

Australian National University



A review of koala habitat assessment criteria and methods

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Cover photo by Murraya Lane

Purpose statement

The purpose of this document is to help the Commonwealth and other natural resource managers interpret advice they receive regarding impact assessments and related management plans for the *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act) listed Koala *Phascolarctos cinereus* (combined populations of Queensland, New South Wales and the Australian Capital Territory), hereafter referred to as the EPBC Act-listed koala. This document collates information on koalas and their habitat that is relevant for determining whether an area is likely to be koala habitat, reviews the benefits and limitations of current methods for assessing koala presence and abundance, and critically assesses the extent that commonly used criteria for evaluating koala habitat are backed by peer-reviewed research. This document is not intended to replace or supersede any Commonwealth statutory documents relating to the EPBC Act-listed koala.

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1 Objectives

The aims of this document are fourfold:

- 1) Develop region-specific koala habitat descriptions based on locally important koala trees that can be used as a starting point by field ecologists to determine if an area is potentially koala habitat
- 2) Provide contextual information on habitat extent, movement, threats, and refugia
- 3) Review the benefits and limitations of current methods for assessing the presence and abundance of koalas in a landscape
- 4) Determine the extent that commonly used criteria for evaluating koala habitat are backed by peer-reviewed research.

2 Introduction

The koala (*Phascolarctos cinereus*, Goldfuss 1817) is an iconic arboreal marsupial endemic to Australia (Figure 1). Koalas have a large distribution across eastern Australia (Map 1), predominantly associated with eucalypt forests containing locally preferred browse tree species. Once abundant, populations in many areas across New South Wales (NSW) and Queensland (QLD) have experienced substantial declines in recent years (McAlpine et al. 2015). Habitat loss for development and other land uses, as well as increasing temperatures, fire severity and drought conditions from climate change are key drivers of population declines. Other threats include disease, dog predation, vehicle strike, habitat degradation, habitat fragmentation, disturbance related changes to forest tree species composition and a lack of clear understanding and agreement over what constitutes koala habitat (Melzer et al. 2000, McAlpine et al. 2015; Ashman et al. 2019).

The koala is a specialist folivore with a diet that consists primarily of eucalypt foliage, although it may occasionally browse from other tree genera. Bark, flower buds and soil can also form trace components of the diet (Au et al. 2017). Across the koala's range, it is thought to regularly eat leaves from over 100 eucalypt species. However, the distributions of most tree species that koalas can eat do not extend across the full geographic range that the koala is known to inhabit, so diets can differ from place to place depending on which tree species are present. In addition, differences in foliar chemistry that dictate browse preference can vary both within and between eucalypt species (Moore et al. 2005; Au et al. 2019). This means that even if the same tree species are present in different areas, koalas' preferences may not be the same because foliar nutritional quality can differ substantially, even among individual trees from the same species (see section 7.3 for additional discussion of nutritional quality variation within and between tree species).

The nutritional quality of eucalypt foliage for koalas and its effects on total intake, tree choice, landscape use and population densities have been the subject of extensive research. The foliar chemical constituents known to drive the foraging decisions and population densities of koalas include foliar nitrogen (a proxy for protein) and plant secondary metabolites, including certain tannins, formylated phloroglucinol compounds (FPCs), and unsubstituted B-ring flavanones (UBFs) (Moore et al. 2005; Moore et al. 2010; Marsh et al. 2014b; Au 2018; Au et al. 2019; Marsh et al. 2019; Marsh et al. 2021). Digestible nitrogen, rather than total nitrogen, may provide a better indication of available protein for many herbivores because this integrated measure incorporates the effects of tannin binding on foliar nitrogen available to the animal for digestion (DeGabriel et al. 2008). Although some foliar nutrients can be influenced by environmental factors that affect their availability to a tree, digestible nitrogen, FPCs and UBFs are largely determined by the genetics of the tree, and no link to soil type, fertility, or geologic substrate have been consistently identified (See section 7.1 for additional information relating to this statement).



Figure 1 A koala (Phascolarctos cinereus)

Source Murraya Lane.





Source Department of Agriculture, Water and the Environment 2021a. Note the map shows the area where the koala is known/likely and may occur. The Listed species distribution refers to the EPBC Act listed koala populations of Queensland, New South Wales and the Australian Capital Territory. The information presented in this map has been provided by a range of groups and agencies. While every effort has been made to ensure accuracy and completeness, no guarantee is given, nor responsibility taken by the Commonwealth for errors or omissions, and the Commonwealth does not accept responsibility in respect of any information or advice given in relation to, or as a consequence of, anything containing herein. The species distribution mapping categories are indicative only.

Like all marsupial eucalypt folivores, the koala is primarily nocturnal. However, unlike most other arboreal marsupials, the koala does not depend on tree hollows for shelter but sleeps sitting on tree branches. Research suggests that koalas may seek out certain trees, including non-eucalypts, for specific thermal properties that provide shade or offer cooler or warmer surface temperatures to help the koala thermoregulate (Ellis et al. 2010; Briscoe et al. 2014). It is likely that these properties are determined by the type of bark, tree size and/or density of canopy foliage, and that any tree or shrub species that possesses the appropriate properties might be favoured for resting, even if it is not favoured as food.

Similarly, food tree preferences, although often associated with specific tree species, are actually driven by the nutritional quality of the foliage which can vary both within and between tree species. Some tree species do tend to have foliage of relatively high nutritional quality across most of their range (e.g. ribbon gum (*Eucalyptus viminalis*), forest red gum and river red gum (*E. teriticornis* and *E. camaldulensis*)). However, that does not mean that the most commonly preferred koala browse tree species are the only tree species that are important indicators of koala habitat, or that they are always higher in nutritional quality than other locally available tree species.

Given the prohibitive time and costs associated with conducting koala feeding studies and assessing browse nutritional quality across the entire range of the koala, we must rely on a combination of local feeding data and nutritional quality information where it does exist, and also make inferences from other methods of assessing the local food tree preferences of resident koala populations. In many areas, there is limited or no locally available data on koala food tree preferences, so we can only make assumptions based on the nearest available data. Other important aspects of koala habitat include ancillary habitat elements such as shelter vegetation that may not contribute substantially to a koala's diet but is important for thermoregulation, and the ground between trees that is traversed by the koala. The ability of koalas to persist in a landscape is further influenced by threats such as heatwaves and drought, predation from dogs, loss of connectivity to other habitat for dispersal and gene flow, the prevalence and severity of diseases (e.g. chlamydia and koala retro-virus), and the risk of vehicle strike (Melzer et al. 2000).

In this document, we identify region-specific, locally important koala tree species that can be used as a starting point to determine whether an area could be habitat for the EPBC Act-listed koala. We discuss how habitat extent, movement, threats and refugia inform our understanding of koala habitat. We then review the benefits and limitations of existing methodology for determining the presence and abundance of koalas once an area is identified as potential habitat. Lastly, we critically assess the extent that assumptions underlying commonly used criteria for evaluating koala habitat are backed by peer-reviewed, published research.

3 Methodology

3.1 Koala management bioregions

The koala is a widely distributed species that can live in many different eucalypt forest and woodland environments ranging from dense, wet coastal forests to semi-arid scattered woodlands, and even suburban or rural landscapes, in patches or strips of native vegetation interspersed with isolated trees. Previous research has demonstrated that models of koala distribution cannot be generalised across regions (McAlpine et al. 2007). The habitat associations of koalas in one area are not necessarily consistent with the habitat associations of koalas in another area. Therefore, it is important to focus on describing koala habitat requirements at scales that are relevant to the landscape use and resource requirements of local populations or metapopulations, which may differ from koala habitat in other areas.

Building on the region-specific work of both NSW and Qld state governments to identify 'locally' important tree species for koala habitat, we combined NSW's Koala Modelling Regions (KMRs) and Queensland's Bioregions to create Koala Management Bioregions (KMBs, Map 2). The ACT is included in the Central and Southern Tablelands KMB along with adjacent territory in NSW. We also considered using the Interim Biogeographic Regionalisation for Australia (IBRA, Map 1), which could be an equally valid approach to subdivide this multi-state, transcontinental area into smaller units that more closely align with the habitat requirements of koala populations. The Queensland Bioregions were initially developed for the use of the Regional Ecosystem Framework in the late 1970s by Stanton and Morgan (1977). They largely align with the IBRA model, which was developed on the basis of vegetation, soil-types and topography (Thackway and Cresswell 1995). The western KMRs from NSW are also modelled using the IBRAs, but most KMRs were modified from the IBRA model to align more closely with NSW Local Government Areas. The extensive work of NSW to identify locally important koala trees at the level of KMRs was the basis for our decision to use them, in combination with the QLD Bioregions, for the KMBs. Arguably, even finer scale descriptions of koala habitat requirements would better capture the essential habitat elements of local koala populations, but this must be balanced with the practicalities of managing this species over wide areas and the data that is available to inform what we know of koala habitat requirements. It is important to note that despite KMBs having distinct boundaries on a map, in practice there is some overlap across KMBs in terms of koala populations, plant communities, tree species, geology, soils and topography.

Map 2 Koala management bioregions for the EPBC Act-listed species across NSW, ACT, and Qld



3.2 Locally important koala trees

Understanding the processes that drive patterns in landscape use by the koala can help illuminate the reasons for differences in habitat requirements between regions. Patterns in tree preferences are largely driven by the nutritional quality of the trees in a given area and potentially other tree attributes that influence their suitability for resting and/or thermoregulation such as tree size, canopy cover and bark type. Given that the nutritional quality of trees can vary within and between species, a commonly eaten, high nutritional quality food tree species in one area may be much less palatable and largely ignored by koalas in another area (Moore and Foley 2000). In addition to variation in the nutritional quality of trees across landscapes, koalas can differ in their choice of food tree species from other koalas in the same region (Marsh et al. 2021). The reasons for this are not entirely understood but may be influenced by differences in the gut microbiome that allow some koalas to eat leaves from trees that other koalas will not eat (Blyton et al. 2019).

Relatively few areas have detailed information on the nutritional quality and/or dietary contribution of locally available tree species to resident koalas. More often, indirect measures of associations between koalas and trees are available, such as observations of koalas in a tree or the presence of koala scat under trees (that is 'tree use'). This type of data is often used to rank the importance of particular tree species to the koala for feeding (Phillips et al. 2000), and there are instances where other methods have supported those findings (Sluiter et al. 2002). However, it is important to recognise that indirect associations of tree preferences may not always reflect actual diet preference (Tun 1993; Hasegawa 1995; Melzer 1995). Koalas spend a lot of time in trees that they do not eat, and both koalas and their scat can be difficult for humans to see. In addition, the likelihood of detecting koalas or scat is influenced by a number of environmental factors that are not consistent across landscapes or vegetation types, creating potential bias (Rhodes et al. 2011; Cristescu et al. 2012; Ellis et al. 2013).

In many areas, there is not a clear distinction between 'feeding' and 'shelter' trees. Many of the trees in which koalas are observed are used to some degree for both activities. However, there are trees that koalas will frequently sit in but feed from very little or even not at all. There are many arguments for including commonly used 'shelter' or 'roosting' tree species in lists of preferred trees for the koala because they may be important to koala habitat in that area. However, there are also management risks associated with giving these trees equal weight to trees that contribute substantially to the koala's diet, which need to be considered. Observed patterns of specific trees being used by the koala for resting are likely to be driven by structural attributes that provide shade or thermoregulation that could be shared by other structurally similar trees regardless of their species, and this can make it difficult to determine whether specific tree species are actually essential components of habitat in some landscapes. Some of the tree species that koalas frequently rest in are much less palatable than their preferred food tree species. That means that koalas may not be able to eat enough of those less palatable trees to meet their energy requirements. Research has demonstrated that increasing the relative abundance of less palatable browse in a landscape reduces the density and likelihood of koalas occurring in that landscape (Au 2018; Au et al. 2019).

A forest or woodland in which all of the trees are a species in which koalas are frequently observed to sit but generally have low palatability (e.g. *Eucalyptus sieberi, Eucalyptus pilularis, E. portuensis* – data from the South Coast of NSW, North Coast of NSW, and Magnetic Island

respectively, (Smith 2004; Au et al. 2019; DPIE 2020b; Marsh et al. in preparation; Blyton et al. in preparation), is unlikely to sustain a koala population. Including low-palatability tree species in preferred koala tree lists can be problematic because landscapes that are not habitat may be inappropriately considered habitat, and threatening processes, such as natural or anthropogenic landscape disturbance that increases the relative abundance of less palatable browse trees, may go unrecognised (Au et al. 2019). Restoration and revegetation activities may also unintentionally increase the relative abundance of less palatable browse species in a landscape in the belief that, as a 'high use species,' they will improve the habitat quality for the koala and that may not be the case. Even species that are typically high-quality browse could decrease the nutritional quality of a landscape if a less palatable chemotype of the same species is unintentionally used for revegetation.

For the purpose of this report, a locally important koala tree (LIKT) is defined as a tree from a species that is regularly browsed by koalas in a particular KMB, such that it could be considered a substantial portion of the koala's diet. What constitutes substantial is subjective, but detailed observations of koalas feeding suggest that multiple observations with feeding bouts of at least 20 minutes would constitute substantial (K Marsh 2021, pers. comms.). We conducted literature reviews to identify tree species that are likely to be LIKT for each KMB. Where data from feeding observations or nutritional quality is lacking, we consider LIKT to be tree species associated with medium or high 'use' by koalas in the published literature or from direct feedback from local koala researchers and/or koala carers in the region. A list of people who provided feedback is available in Appendix A. Where indirect observational data was at odds with nutritional data, observational feeding data, or faecal diet analysis data from the same area, the feeding/nutritional/diet data was given precedence. Otherwise, the tree was assigned its rank based on all sources specific to that KMB. Where sources disagreed in ranking, the Koala Habitat Information Base for NSW (DPIE 2019) was give preference, but otherwise the tree was assigned the highest rank from all available sources. Sources for all listed LIKT in each KMB are reported in Appendix B.

The presence of LIKT can be used in conjunction with appropriate koala assessment methods (reviewed in section 6) to determine whether an area is likely to be koala habitat. The combination of koala occurrence and LIKT provides a strong indication that an area is koala habitat. However, it is important to recognise that the absence of koalas does not mean that an area with LIKT is not potential koala habitat. Landscapes may be unoccupied due to temporal shifts in habitat quality from disturbance (e.g. fire, logging), heatwaves, disease, and other threats (e.g. feral dogs, traffic), or historical reasons (e.g. hunting, land-clearing). If the climate is suitable, it may be possible for koalas to recolonise those areas given sufficient time and connectivity to other populations and appropriate mitigation of remaining threats that could continue to influence the persistence of koala populations in that area. It can also be very difficult to establish true absence given the cryptic nature of koalas, and potential for low densities across large areas in some landscapes.

In some areas, the availability of certain tree species and other vegetation types not commonly recognised as important food may still be essential for koala survival due to the shelter or other resources they provide e.g. *Callitris glaucophylla* (Pilliga, NSW, Kavanagh et al. 2007), *Callitris columellaris* (North Stradbroke Island, Queensland, Woodward et al., 2008; Cristescu et al., 2011), *Acacia harpophylla* and *Melaleuca bracteata* (Queensland Brigalow, Ellis et al., 2002). These species can provide important ancillary habitat elements when they co-occur

with LIKT. Although, these species do not constitute habitat in the absence of LIKT, they are thought to make an important and potentially necessary contribution to koala habitat in many regions. For this reason, we have also included a separate table for each KMB that includes ancillary habitat trees that are unlikely to be preferred browse trees, but are likely to make important contributions to koala habitat based on documented koala use in peer-reviewed literature, SEPP (SEPP 2021), and/or direct feedback (Appendix A).

The existing peer-reviewed publish literature does not support making a distinction between 'breeding' and 'non-breeding' habitat for the koala. Both males and breeding females can live in high and low quality habitat, although population size tends to decrease with decreasing habitat quality. The percentage or proportion of important koala browse tree species in a landscape are commonly used to assess and rank habitat, and these are reviewed in section 7. In addition, we discuss important considerations of habitat extent and connectivity and threats that can influence the persistence of koalas in sections 4 and 5, respectively.

4 Habitat extent and connectivity

In line with the National Recovery Plan for the EPBC Act listed Koala (DAWE 2022) Koala *Phascolarctos cinereus* habitat can be considered 'the total set of resources required by koalas to meet the needs of individual survival and reproduction.' The National Recovery Plan goes further to also include 'how those resources are arranged in a landscape to maintain viable metapopulation processes.' In this way, habitat can be considered at multiple scales, both what is required for individual koalas to meet their food and shelter requirements and what is required for koala populations to remain viable. **Determining the minimum spatial extent required to support koalas at either the individual scale or the population level is complicated by the fact that koalas can persist in highly fragmented landscapes and the amount of area needed differs widely across the range of the koala due to spatial and temporal differences in the quality and availability of resources.**

Koalas have highly variable home range (HR) sizes both within and between KMBs. Males typically have larger HRs than females and HR size also increases in areas where trees are more widely spaced (Whisson et al. 2016). Browse nutritional quality likely plays a role in determining HR size as well. The smallest home ranges reported are less than 1 ha (e.g. Ramsay, 1999; White, 1999; Ellis et al., 2011; Goldingay and Dobner, 2014) and the largest are well over 100 ha (e.g. Melzer and Lamb, 1994; Ellis et al., 2002; Davies et al., 2013). Even in the far western KMBs of NSW and QLD, koala home range sizes in strips of riparian vegetation dominated by *Eucalyptus camaldulensis* can still be relatively small (that is 1 to 2 ha, Kavanagh et al. 2007). However, HR sizes are often larger in these western woodland ecosystems (Ellis et al. 2002; Davies et al. 2013; Crowther et al. 2021).

The amount of habitat required to support a population of koalas is also highly variable and is likely to be influenced by similar factors as home range size (e.g. habitat quality and spacing of trees in the landscape). A questionnaire sent to koala researchers as part of this review asked these experts 'what is the minimum spatial extent to support a koala population in your region.' We received responses that included 'less than 1 ha patches, in association with backyard and street trees in high quality habitat' (D de Villers 2021, pers. comms. for SE Queensland) to 'areas need to be very large (in the order of many thousands of hectares) to maintain a genetically resilient population over time for many of the koala populations in NSW' (R Montague-Drake 2021, pers. comms.). The reason for these large differences in opinion about the minimum extent of habitat required for a population, even in ecologically similar regions, may be a result of differing definitions of population.

Where a population is simply a set of individuals that live in the same habitat patch and interact with one another, commonly forming a breeding unit within which the exchange of genetic material is more or less unrestricted (synonyms: local population, subpopulation, deme), then it would be sensible that, 'even small patches of high-quality habitat may support koala populations where the connecting vegetation or landscape matrix allows for safe dispersal opportunities for emigration and recruitment,' (John Callaghan personal comms for SE Queensland). Where an interpretation of population also incorporates metapopulations and/or includes arbitrary minimum population sizes, then larger areas were indicated by respondents. For example, John Turbill (2021, pers. comms.) discussed NSW Areas of Regional Koala Significance (ARKS) in response to this question and provided an extract from a report review by Biolink (in prep) to explain that 'An ARKS comprises a contemporaneous koala metapopulation that is both spatially and demographically independent and sufficiently large enough in terms of available habitat so as to be able to support a minimum aggregated population size of 500 adult koalas. The minimum aggregated population size notionally comprises one or more koala population cells or 'Hubs', each of which in turn comprises an arbitrary minimum aggregated population size of 50 adult koalas.' When an area is required to support a relatively large number of individual koalas (that is, 50 or even 500), then it would typically need to be much larger than an area required to support a smaller population. The definition of habitat extent or minimum area required to support koalas depends largely on the number of koalas that an area would need to support.

Defining minimum habitat extent or 'patch' size is further complicated by the fact that koalas can move large distances on the ground. Connectivity between habitat 'patches' therefore does not require a continuity of vegetation. Scattered trees themselves, in addition to being stepping stones between patches, can actually extend the area of a habitat patch into a landscape that might otherwise be considered a matrix and effectively enlarge the size of that habitat patch. For this reason, koalas and koala populations can persist in highly fragmented landscapes such as peri-urban areas and scattered paddock trees in agricultural land where koalas regularly move across the ground for tens or even hundreds of meters (Ramsay 1999; Marsh et al. 2014b). **Walking on the ground is how koalas typically travel between trees, so the ground itself forms an essential component of koala habitat, without which movement between trees would be hindered or impossible.** In addition to regular movements across the ground between trees within their own HRs, koalas, particularly subadult males but also females, are known to disperse across distances of 1 to 3 km but sometimes over 10 km (Melzer 1995; White 1999; Dique et al. 2003a; Matthews et al. 2016).

Scattered trees regularly contribute to the suite of trees within a HR that forms a koala's habitat and also can provide essential shelter and food to help koalas move more safely for longer distances across the landscape during dispersal. For this reason, rather than a patch-corridormatrix landscape use model (Forman 1995), the larger connectivity of the system and overall 'thresholds' of usable vegetation (that is, individual trees and patches) across wider areas may be a more useful way to quantify the spatial extent of a landscape that is required to support koalas and koala populations (White 1999; Rhodes et al. 2008). Although thresholds have been shown to be useful for understanding the minimum area required before koala occurrence declined substantially, these thresholds differed across regions, which demonstrates that habitat minimums required for one area cannot be safely extrapolated to another (Rhodes et al. 2008). In addition, thresholds may not be the best model for all landscape types. Smith et al. (2013) found that linear relationships between koala occupancy and habitat amount were more appropriate than thresholds in the Mulga Lands KMB and recommended a minimum distance of 1000 m from creek lines dominated by *E. camaldulensis* to conserve koala populations in that area. Thresholds and/or minimum habitat extents have not been established for most areas and the scale best suited to establish these is typically much smaller than KMBs (Rhodes et al. 2008).

The Commonwealth does not use any patch size or isolation distance for its species distribution model (SDM) for the koala, which is probably most appropriate since the resolution of the continental scale environmental layers used in the modelling cannot identify scattered, isolated trees or very small forest/woodland patches (C Meakin 2021, pers. comms.). However, for mapping koala habitat itself, the Commonwealth uses an area of 500 ha east of the 800 mm

rainfall isohyet and 1000 ha when west as a minimum habitat patch size, and 10 km as the threshold for considering a patch isolated. This is roughly based on guidelines from the previous (now superseded) EPBC Act Referral Guidelines for the Vulnerable Koala (DoE 2014), which assigns the highest habitat value score to inland habitat that is part of a contiguous landscape \geq 1,000 ha, the second highest to contiguous vegetation < 1000 ha but > 500 ha, and coastal habitat is given the highest score for contiguous landscapes ≥ 500 ha followed by < 500 ha but > 300 ha. The 2014 Commonwealth Referral Guidelines rankings did not consider whether smaller vegetation patches and scattered trees contribute to koala habitat and the persistence of koala populations in an area (DoE 2014). Under the previous guidelines (now superseded) referral was not required for impacts to areas less than 2 ha, with areas between 2 ha and 20 ha required to have relatively high habitat scores (that is >8) before automatically triggering the need for an EPBC ACT referral (DoE 2014). Similar thresholds are not used at a state level for QLD but they are in NSW where the application of State Environmental Planning Policy (Koala Habitat Protection) 2021 (SEPP 2021) includes areas of 1 ha or larger, except in a few local government areas where an approved koala plan of management has different requirements. The way that smaller habitat patches and scattered trees are valued in the future could have a large impact on the persistence of koalas, particularly in areas that are already highly fragmented (Rhodes et al. 2008; Barth et al. 2020).

Koala habitat maps and species distribution models can provide indicative information on areas that may be koala habitat. However, the information should not replace local field data and site observations. It is rare for maps to be fully ground-truthed and large-scale mapping is often limited in its ability to predict features at smaller scales that are important to landscape use by koalas. In addition, models and maps created with data from one area may lose predictive capabilities when applied to other areas (McAlpine et al. 2007).

5 Threats

Beyond habitat loss, there are a number of key threats to the survival of individual koalas and koala populations that include the increasing severity and frequency of heatwaves, drought and fires from climate change, diseases such as chlamydia and koala retro-virus, dog predation, vehicle strike, habitat fragmentation, habitat degradation and disturbance related changes to forest tree species composition (McAlpine et al. 2015; Ashman et al. 2019). Detailed summaries of these threats are available in the National Recovery Plan for the Koala *Phascolarctos cinereus* (combined populations of Queensland, New South Wales and the Australian Capital Territory) (DAWE 2022) and the Consultation Document on Listing Eligibility and Conservation Actions for *Phascolarctos cinereus* (Koala)(DAWE 2021b).

The presence and severity of threats can influence the likelihood that otherwise habitable land is occupied by koalas, and therefore affect habitat quality in terms of its ability to support koala populations. Multiple threats are usually present in a given habitat regardless of the location, and the scale that threats act on koalas and koala populations is typically much smaller than the spatial area that comprises any KMBs. However, some threats are more prevalent in some areas, and understanding the spatial and temporal influence of threatening processes is critical for effective mitigation. In addition to the threats listed above, a lack of clear understanding over what constitutes koala habitat can result in inappropriate conservation and management decisions adversely impacting the persistence of koala populations (Cristescu et al. 2019b). Here we briefly review some key threats to koala populations with a focus on how they may influence koala habitat based on evidence from peer-reviewed, published literature.

5.1 Climate change

The impacts of climate change associated drought and heatwaves on Eucalypt and Corymbia dominated forests have already been observed in many areas. This includes tree mortality and dieback in response to drought and warming (Nolan et al. 2021). Modelled data suggests that climate change will substantially reduce the range of several key koala browse tree species in the future (Adams-Hosking et al. 2012). In addition to affecting koala habitat, increasingly severe heatwaves and drought can also directly impact animal physiology. If an animal is unable to dissipate heat, it can die from heat stroke in hot environments. However, even before temperatures are extreme enough to cause mortality from direct heat exchange, animals decrease their food intake to avoid contributing additional heat burden from foraging and the digestion process (Youngentob et al. 2021). This is particularly problematic for species that survive on a low energy diet and that get the majority of their water from their food, like the koala (Youngentob et al. 2021). Eating less for prolonged periods can affect animal fitness and reproductive success. Koalas that eat less will also dehydrate more quickly since they obtain most of their water from their food, even if the leaves they eat contain sufficient leaf moisture (Beale et al. 2018). Leaf moisture itself can decrease during periods of extreme heat and drought, which may further contribute to dehydration during periods of heat stress (Clifton 2010). Hot and dry conditions can decrease water availability in leaves and the environment, which is thought to be a key limiting factor for koalas in parts of their range, particularly in western QLD and western NSW (Clifton et al. 2007; Clifton 2010; Davies et al. 2014).

Mechanistic climate models can provide advice on what habitat is unlikely to remain viable for koala populations due to increasingly severe heatwaves and drought from climate change exceeding the threshold of survival for the koala (Seabrook et al. 2014; Briscoe et al. 2016). Based on those models, it is highly probable that large areas in western NSW and western QLD that were once koala habitat, will not be viable in the near future (< 50 years) (Briscoe et al. 2016). However, landscapes are heterogenous and even within these broader regions of future climate intolerance, there are likely to be refugia that allow the koala to persist in those regions for some time into the future. The availability of surface water may be an important ancillary habitat element of refugia in these areas. Given the potential for refugia and wider areas of potential habitat that would provide connectivity between refugial populations will be particularly important to the persistence of koalas in the future, especially in the western part of the koala's range.

Climate change is also likely to increase the prevalence and severity of wildfires (Bowman et al. 2021). Fire, as a disturbance event, can result in very high immediate mortality of animals, but does not necessarily render a landscape uninhabitable to koala populations. Therefore, fire alone should not be a reason to discount areas that may otherwise be koala habitat. Many eucalypt species can resprout from epicormic buds under their bark, and produce new leaves relatively quickly after fire (Burrows 2002). Koalas have been observed in burnt habitat within months of severe fire (Curtin et al. 2002; Lunney et al. 2007; Matthews et al. 2007), and rates of survival and reproduction can be similar between burnt and unburnt landscapes, suggesting that burnt habitat with sufficient epicormic regrowth and/o This is roughly based on guidelines from the previous (now superseded)r remaining mature foliage in palatable species can provide adequate food resources (Lunney et al. 2007; Matthews et al. 2007). Thus, despite initial, and potentially substantial reductions in koala abundance post-fire, koala populations can recover over time if there is sufficient connectivity to surviving source populations (Lunney et al. 2002; Matthews et al. 2016). However, in some situations, fire can result in longer-term shifts in ecosystem structure and composition that can influence habitat quality for the koala for decades or longer (see habitat degradation below).

5.2 Habitat degradation

Habitat degradation can occur over short timeframes (e.g. the immediate removal of some food/shelter trees), through stochastic disturbance (e.g. fire) or from longer term processes (e.g. shifts in floristic composition due to changes in seedling recruitment/survival). Some changes in habitat quality may be temporary because landscape composition and structure can recover. However, disturbance can also result in long-term shifts in the structure or composition of forests that decrease the nutritional quality of a landscape and it's carrying capacity for the koala into the foreseeable future (Au et al. 2019). For example, some areas on the South Coast of NSW and East Gippsland in Victoria that have seen repeated logging of native forests and fire have experienced shifts in vegetation communities that favour disturbance adapted eucalypt species such as Silvertop Ash (Eucalyptus sieberi) (Lutze and Faunt 2006), which has very low nutritional quality across the areas where it has been sampled. Forests in that region that are monocultures or near monocultures of Silvertop Ash are unlikely to support koala populations without widespread revegetation with more palatable local browse species (Au et al. 2019; DPIE 2020a).

5.3 Habitat fragmentation

Although koalas can persist in highly fragmented vegetation, habitat fragmentation can result in remaining areas of vegetation that are too small to support koala populations or are so isolated that the distance to another stepping stone or habitat patch acts as a barrier to movement. It is important to note, however, that koalas regularly walk across the ground for tens or even hundreds of meters between trees and can move longer distances when dispersing. Relatively isolated trees and patches of native forest or woodland can act as stepping stones and provide a corridor of connectivity between larger habitat patches. Therefore, size measurements involving habitat patches should include any isolated locally important koala trees or patches of those trees within a distance regularly traversed by koalas in that region, as well ancillary habitat elements including the ground between the trees.

5.4 Vehicle strike and dog predation

Vehicle strike and dog predation are significant threats to koalas, particularly in urban areas, despite the frequent occurrence of koalas in areas with relatively high human occupancy (McAlpine et al. 2015). Wild dogs can contribute substantially to koala mortality in rural and native forest/woodland environments as well. Vehicle strike is a serious risk to koalas near major transport routes that do not have effective mitigation strategies in place to prevent koalas from crossing busy roadways and provide alternatives for koalas to traverse these high-risk routes, such as underpasses or overpasses. Some koala habitat assessment methods provide higher scores to landscapes where there is no evidence of these threats to the koala (DoE 2014). If mortality was sufficiently high, vehicle strike and dog predation could contribute to habitat sinks; however, the existing peer-reviewed literature does not provide clear guidelines for quantifying the contribution of these threats to habitat quality.

5.5 Disease

A recent review of publications that discuss threats to the koala found that 84% of those publications related to koala diseases, followed by habitat loss, fragmentation and degradation combined (25%) and then climate change (20%) (Ashman et al. 2019). This should not be taken to mean that as a risk to koalas, diseases are of more concern than these other threats, but disease contributes substantially to population declines in some areas (Rhodes et al. 2011; Robbins et al. 2019). The 2 main diseases of concern for the koala are chlamydia and koala retrovirus (KoRV) (Ashman et al. 2019). Interestingly, many more koalas may be infected with the pathogens that can cause disease than show clinical signs of the disease, and this can make it difficult to demonstrate that disease is a major driver of decline in many areas (McCallum et al. 2017). Chlamydia and KoRV are found in most koalas and many live with the infections and never show outward signs of illness or suffer measurable reproductive consequences (Polkinghorne et al. 2013; Quigley and Timms 2020). The progression from infection to disease may be influenced by secondary factors that cause chronic stress, since the production of stress hormones like glucocorticoids have a strong negative impact on the immune system (Narayan and Williams 2016). Habitat loss, disturbance, degradation, heat-stress, poor nutrition, and other stressors likely play a role in whether common pathogens progress to clinical disease that can negatively affect the health of individual koalas and populations (Narayan and Williams 2016).

6 Assessing koala presence and abundance

Key points:

- There are many widely used methods for assessing koala presence and abundance.
- It is important to recognise the limitations of each method to make appropriate inferences from the data.
- Some methods may be better suited than others to address specific questions or to use in certain environments.
- True absence cannot be demonstrated without repeated surveys across different seasons using multiple survey techniques.

Reliable data on the presence and/or abundance of koalas should be an important component of koala habitat assessments and these data are a valuable asset to inform management decisions. However, koalas are a cryptic species, and it is difficult to distinguish between lack of detection and true absence (Woosnam-Merchez et al. 2012), which makes abundance estimates inherently uncertain. Furthermore, in low density populations, survey conclusions can be strongly influenced by only a few missed observations (Woosnam-Merchez et al. 2012; Hamilton et al. 2020). Data that is collected or interpreted without acknowledging survey method-specific limitations can therefore lead to vastly inaccurate estimates of koala abundance and habitat quality, with potentially serious downstream consequences for understanding the true biological impacts of major development projects and determining appropriate mitigation strategies or offsets.

There is no single technique or widely accepted method to survey koalas (Wilmott et al. 2019). All of the commonly used methods have strengths and limitations (Table 1 and Table 2), and a method that works well in one location may be unsuited to another. Ultimately, the survey technique that is selected affects koala detectability, the type of data that can be obtained, and its capacity to inform decision making. Where there is a need to critically evaluate the potential impacts of major projects, multiple techniques should be used to determine koala presence and/or to estimate density (Crowther et al. 2021). Likewise, in order to estimate true absence, it is necessary to conduct repeat surveys that take temporal variation into account, often utilising multiple methods. Commonly used direct and indirect koala survey methods are outlined below, with the length of discussion for each method largely influenced by the amount of published, peer-reviewed research outlining uses, benefits and limitations.

6.1 Direct observation techniques

Direct observation methods rely on the physical sighting of a koala, and can be undertaken during the day (e.g. transect searches) or at night (e.g. spotlighting), with or without additional aids (e.g. thermal drones or koala detection dogs). Direct koala sightings can provide valuable information about sex, reproductive status (if surveys are undertaken when back young are present), health (e.g. prevalence of symptomatic chlamydia), and landscape and tree use (e.g. Whisson et al. 2016). These characteristics may be particularly useful in a management context where they demonstrate the presence of a population. When conducted with appropriate recognition of limitations, some direct survey methods can also provide estimates of koala density or abundance in addition to presence.

Like any survey technique, it is important to recognise that direct observation methods will miss some individuals (Dique et al. 2003b; Dique et al. 2004; Corcoran et al. 2019; Witt et al. 2020) and it may be necessary to conduct repeat surveys on multiple occasions to improve detection rates, especially in low density populations. A major limitation of many direct observation techniques is that they can require intensive survey effort over large areas for limited data. In addition, the experience of observers (Dique et al. 2003b), the use of aids such as koala detection dogs or thermal drones (Witt et al. 2020) and the structure of the landscape (Corcoran et al. 2021) can have a large impact on the likelihood of seeing a koala.

6.1.1 Transect and point surveys

Transect surveys, most commonly strip transects, line-transect distance sampling, or double count transects, involve searching for koalas in trees on both sides of pre-determined lines. During strip transect surveys, multiple observers concurrently walk parallel lines at closely spaced intervals so that each tree is searched from multiple angles in an attempt to observe every individual within the defined study area (e.g. Dique et al. 2004). In contrast, distance sampling is usually undertaken along a single transect line, which is then repeated at spaced intervals (Dique et al. 2003b). The distance from the line at which a koala is observed is recorded and used to calculate a probability of detection. Double count transects are similar to distance sampling, but each transect is surveyed by 2 independent observers (Hagens et al. 2018; Ashman et al. 2020). All transect survey methods are labour intensive when applied over large areas, but they do not require highly specialised skills and can be cheaper than some other direct observation methods (Crowther et al. 2021).

In addition to demonstrating koala presence, data from strip transect, distance sampling and double count surveys can be used to estimate the number of koalas at a site, provided that several important criteria are satisfied. For strip transects, correction factors must be applied to account for koala detectability based on the known accuracy of koala surveys in similar vegetation communities (Dique et al. 2003b; Dique et al. 2004). For example, 16 to 29% of radio-collared koalas were missed during strip transect surveys in Queensland (Hasegawa 1995; Dique et al. 2001). In distance sampling it is possible to correct for the probability of detection, as long as koalas on the transect line are detected with a probability close to 1.0 (Dique et al. 2003b). However, Dique et al. (2003b) reported that inexperienced observers saw fewer koalas than experienced observers, suggesting that this assumption may sometimes be violated. Double count surveys can overcome this limitation, because the proportion of koalas missed by each observer can also be estimated (Ashman et al. 2020). Another limitation of distance sampling is that a minimum number of sightings (60 to 80) is required to estimate detectability, which may not be possible in low-density populations (Dique et al. 2003b; Crowther et al. 2021). In high density populations, distance sampling produced similar estimates of koala abundance to strip transect surveys (Dique et al. 2003b), as well as to mark-recapture-based estimates and home range analysis (Crowther et al. 2021). The latter 2 methods, however, produced more precise estimates with smaller confidence intervals (Crowther et al. 2021).

Phillips and Callaghan (2014) proposed that koala density and abundance can also be reliably estimated by extrapolating the number of sightings of koalas within a 25 m radius of focal trees

repeated across a grid to the total area of the study site. This method supposedly gave similar estimates to transect searches in a survey for a local council in Queensland (Phillips et al. 2007). However, in the only test of this method in the peer-reviewed scientific literature, density estimates for koalas in the Port Stephens area were 0 koalas per hectare in 6 of 7 sites at which koalas were detected using other methods (Witt et al. 2020). Specifically, only one koala was located using the point surveys, while 11 were located with thermal drones and 4 with spotlighting. Thus, the method does not appear to be reliable.

6.1.2 Spotlighting

Night-time spotlighting searches, which involve detecting reflected eye shine from koalas, are commonly used in conjunction with transect or point survey methods and are therefore subject to many of the same strengths and limitations. However, one advantage of spotlighting over the equivalent daylight surveys is that koalas are often detected more effectively (Wilmott et al. 2019). Like daylight transect surveys, spotlighting can be used to estimate koala abundance as long as the necessary conditions for survey design and analysis are met, and where there is an understanding of detectability. One specific consideration is that, despite an increase in the chance of detecting koalas, spotlighting remains a fairly inefficient method for locating koalas in low density populations (Law et al. 2020; Witt et al. 2020). Witt et al. (2020) estimated that the probability of detecting a koala by spotlighting in a low-density population was about 39%. Furthermore, koalas were not detected at 3 of 7 sites at which they were detected using both thermal drones and scat surveys (Witt et al. 2020). Spotlighting therefore underestimated koala occupancy and density relative to estimates obtained from thermal detection drones (Witt et al. 2020).

6.1.3 Trained koala detection dogs

Dogs that are trained to detect live koalas have the potential to enhance the probability of locating koalas during standardised ground-based surveys relative to human observers (Cristescu et al. 2020). Worldwide, wildlife detection dogs generally outperform other monitoring methods at detecting target species, although performance is dependent on training, target density and study design (Grimm-Seyfarth et al. 2021). Despite the existence of koala detection dogs in Australia, there is currently no peer-reviewed assessment of their capabilities for direct koala observation surveys. Instead, the peer-review research involving detection dogs and koalas pertains to their ability to detect scats, rather than koalas directly, which we discuss in the section 6.2 on indirect detection methods. Given the cryptic nature of koalas, it is likely that appropriately trained dogs could outperform human observers as they have been proven to do for other species, but more research is required to quantify the direct detection capabilities of dogs relative to other methods.

6.1.4 Mark-resight or mark-recapture

During mark-resight and mark-recapture studies, all observed individuals are usually captured and tagged, allowing population size to be estimated based on the proportion of marked to unmarked individuals captured or sighted during subsequent surveys. When koalas are caught for marking, additional data can also be collected on sex, body weight, condition, age, and disease status, which can contribute to a broader understanding of sex ratios, health and age distribution within a population. Density estimates from mark-recapture studies can be reasonably precise, but they require animal ethics approval and personnel who are specifically trained in the capture and handling of koalas (White and Kunst 1990; Crowther et al. 2021). An alternative mark-resight survey method that does not require capture involves 2 experienced people independently undertaking a thorough search for koalas within a site. Population size can then be calculated based on the number of koalas seen by both searchers (recapture) relative to those that were missed by one (Masters et al. 2004). Mark-resight and mark-recapture studies can be more labour intensive than transect surveys, but are generally better suited to estimating abundance in lower-density populations.

6.1.5 Thermal detection drones

Drones (also known as remotely piloted aircraft systems (RPAS) or unmanned aerial vehicles (UAV)) mounted with thermal cameras are a relatively new method for directly detecting and counting koalas. Surveys are usually undertaken in the early hours of the morning or at first light to maximise the difference between the thermal signature of koalas and the surrounding environment, and commonly follow a lawnmower pattern of parallel line-transects (Corcoran et al. 2019; Beranek et al. 2020; Corcoran et al. 2020; Hamilton et al. 2020; Witt et al. 2020). Koalas are detected by the presence of a bright thermal spot in the relatively darker surrounding canopy (Beranek et al. 2020). Thermal imagery can either be processed on site in real time, with validation by on-ground observers or via a drone-mounted colour camera (e.g. Beranek et al. 2020; Witt et al. 2020), or off site by either manual processing or machine learning algorithms (e.g. Corcoran et al. 2019; Corcoran et al. 2020; Corcoran et al. 2021).

In optimal conditions, thermal drone surveys have significantly higher rates of koala detection than ground-based direct observation methods, and the search time per koala detection can also be substantially lower than for other direct observation methods, such as spotlighting (Witt et al. 2020). As a consequence, thermal drones are better suited for surveying low density koala populations than are many other direct observation methods (Witt et al. 2020). Drones can also be used to survey areas that are difficult to access on foot, reducing potential survey bias (Leigh et al. 2019). However, thermal drone surveys require specialised equipment, training and experience that may not be accessible to most field practitioners. Surveys conducted in suboptimal conditions or with inexperienced pilots and/or data analysts may fail to detect koalas even when they are present (personal comms Karen Marsh). Drones also have the potential to disturb koalas and other non-target species, although Beranek et al. (2020) did not observe obvious reactions to drone presence, but noted that this may differ if surveys were conducted during the breeding season of territorial animals.

Thermal drone surveys can be used to estimate koala density either by undertaking a complete census of the area of interest, or by surveying random portions of the site and extrapolating the results to unsampled areas (Witt et al. 2020). However, like all survey techniques, there are multiple factors that must be considered when interpreting the results. One is that the terrain, temperature, wind speed, canopy cover and height of the koala in a tree can all affect detectability of koalas by thermal drones (Witt et al. 2020; Corcoran et al. 2021). Pilot experience, drone speed and height, and the use of manual versus automated processing of imagery can also play an important role in whether koalas are detected, and influence the rate of false detections (that is, thermal signatures from other sources that are incorrectly identified as koalas) and duplicate detections (that is, the same koala detected twice due to overlapping images from adjacent transect lines (Baxter and Hamilton 2018; Corcoran et al. 2019; Corcoran et al. 2020; Hamilton et al. 2020; Corcoran et al. 2021). For example, Corcoran et al. (2019) found that on average, 52% of radio-tracked koalas were detected using manual processing of thermal drone imagery, while 85% were detected with automated processing.

6.1.6 Radio-tracking

Radio-tracking and GPS-tracking studies allow marked individual koalas to be located repeatedly over a set time period, facilitating the collection of valuable ecological data such as tree species used, distances moved, social interactions, fecundity, rates of survival and cause of mortality (Beyer et al. 2018). Provided enough data points are collected, locations can also be used to calculate home range sizes and to understand whether individuals are resident or dispersing (Dique et al. 2003a). Recent studies suggest that the sizes of koala home ranges can be used to infer population densities (Crowther et al. 2021); koalas in high-density populations with access to high-quality food resources tend to have smaller home ranges (Whisson et al. 2016).

To accurately estimate koala densities from home range size, it is first necessary to understand the extent to which the home ranges of adjacent individuals overlap within the study area, and to ensure that movements are not associated with dispersal, mating, anthropogenic disturbance, or patchy resources (Crowther et al. 2021). Where these factors are known, Crowther et al. (2021) showed that estimates of koala density from home range analyses were similar to estimates from both mark-recapture and transect surveys. Radio-tracking studies, however, were costlier, more resource intensive, time consuming, and required animal ethics approval and specialised personnel relative to other methods (Crowther et al. 2021).

6.1.7 Camera traps

Camera traps have become a popular addition to wildlife surveys over recent years; they are non-invasive, relatively easy to deploy and interpret, and can potentially detect cryptic species. Camera traps have been used to monitor the use of wildlife road-crossing structures by koalas (Dexter et al. 2016; Goldingay and Taylor 2017), and to confirm that koalas were responsible for unusual bark scarring on specific trees (Au et al. 2017). On their own, however, camera traps may be a relatively inefficient method to establish koala presence at a site because the predominantly arboreal lifestyle of koalas means that they are less likely to encounter cameras than ground-dwelling species, and their specialist diet also means that they are unlikely to be attracted to baits.

6.2 Indirect survey techniques

Indirect survey methods depend on locating evidence of the presence of koalas, such as faecal pellets or vocalisations. These methods are generally lower cost alternatives to direct observation techniques, and are therefore popular in monitoring programs and for environmental impact assessments. Most indirect survey techniques are better suited to determining activity levels or occupancy rather than for estimating abundance or density. Even then, however, care must be taken when interpreting occupancy data if sample sizes are small, or when surveys are only undertaken at a single point in time (Cristescu et al. 2015; Lollback et al. 2018).

6.2.1 Faecal pellet (scat) surveys

Koala faecal pellet surveys involve searching for koala scats under trees within a specified area of interest. Koala faecal pellets can be distinguished reasonably well from the scat of most other Australian mammals (Jiang et al. 2019) and can persist in the field for months depending on environmental conditions (Cristescu et al. 2012). Koala scats can often be easier to locate than the koalas themselves (Curtin et al. 2002; Mossaz 2010; Witt et al. 2020). Scat survey methods

are also generally straightforward and require few resources, which makes them appealing for environmental impact assessments. A number of standardised faecal pellet survey methods have been used for this purpose, including the spot assessment technique (SAT), rapid-SAT, regularised grid based-SAT (RGB-SAT), balanced koala scat survey (BKSS), and koala rapid assessment method (KRAM), which can be undertaken by human observers or using specifically trained koala scat detection dogs. These methods, which are discussed individually below, differ in their approach to selecting which trees to search, the number of trees examined, the search radius around trees, and/or the time spent searching.

There are several factors that must be considered when interpreting the results of scat surveys. First, while the detection of koala faecal pellets indicates the presence of koalas, an inability to locate scats does not demonstrate that koalas are absent. 'False negatives' occur when koalas are present but are not detected during surveys. Woosnam-Merchez et al. (2012) outlined several scenarios in which false negatives can occur. These include: 1) faecal pellets were deposited under other trees at the site but not under survey trees, 2) faecal pellets were deposited under survey trees but not detected because they were obscured by the ground layer, or 3) faecal pellets were deposited under a different portion of the survey tree than the search location. False detections are more likely to occur when the search time per tree is limited (Cristescu et al. 2012; Woosnam-Merchez et al. 2012; Jiang et al. 2019), the search area is restricted to a small portion of the canopy (Woosnam-Merchez et al. 2012), koala densities are low (Jiang et al. 2019), and/or when there is complex ground cover (Cristescu et al. 2012). For example, (Jiang et al. 2019) demonstrated that human **observers can miss up to 46% of trees with scats**.

A second consideration is that the selection of sampling locations within a site can influence estimates of koala occurrence. For example, Cristescu et al. (2019b) demonstrated that surveys that are targeted towards habitats that are perceived to be of high quality to koalas can substantially underestimate koala occurrence relative to surveys that adopt a uniform sampling strategy. Third, while carefully designed scat surveys can provide valuable information about koala presence, tree species use and habitat occupancy, it is important to avoid over-interpreting data (Woosnam-Merchez et al. 2012). From scat detection surveys alone, it is not possible to determine the number of individuals, their sex, health, diet, home range size, and whether they are resident or transient. Furthermore, although scat detection rates correlate with koala abundance in some areas (e.g. Ellis et al. (2013), koala population metrics cannot be inferred at sites where the relationship between activity levels and koala abundance has not been established. This is because scat detectability, scat deposition rate and decay rates all vary between locations (Phillips and Callaghan 2011; Rhodes et al. 2011; Cristescu et al. 2012; Ellis et al. 2013). If required, scat surveys can be supplemented with laboratory analyses to gain additional information. For example, DNA extracted from scats can be used to identify the number of unique individuals and their sex (Wedrowicz et al. 2013).

Spot assessment technique (SAT) and rapid-SAT

The spot assessment technique (SAT) was developed by Phillips and Callaghan (2011) to reduce the time, costs and resources associated with direct koala surveys. The technique involves searching for scats for 2 minutes (or until the first scat is detected) within a 1 m radius of the base of a central tree and its nearest 29 neighbouring trees. All trees must be at least 10 cm diameter at breast height (dbh), and, if available, the central tree should be a species considered to be important for koalas (Phillips and Callaghan 2011). The technique can be paired with a regularised grid-based sampling design (RGB-SAT) or other random, stratified or systematic plot selection methods to determine the number of replicates and location of SAT survey plots within a site (e.g. Lunney et al. 2000; Phillips and Callaghan, 2011; Au et al. 2019; Witt et al. 2020). SAT surveys can be used to estimate site occupancy (that is, the presence of koala scats under at least one tree) and koala activity levels (that is, the proportion of trees under which scats are observed relative to the total number of trees sampled) (Phillips and Callaghan 2011).

Common criticisms of the SAT include: 1) A high proportion of scats are deposited outside of the 1 m radius (Ellis et al. 1998), which can lead to a substantial number of false negatives, especially when koala activity levels are low (Jiang et al. 2019). 2) It can take more than 2 mins to effectively search some types of ground cover around the base of trees (e.g. deep bark or leaf litter), potentially inflating false negatives in landscapes with complex substrates (Cristescu et al. 2012; Woosnam-Merchez et al. 2012; Jiang et al. 2019). 3) The subjective selection of the central tree violates the principle of randomness (Dique et al. 2004; Cristescu et al. 2012; Woosnam-Merchez et al. 2012; Jiang et al. 2019). Recent tests of the SAT show that it can be effective at detecting site occupancy in areas where koala densities are medium to high, but it can produce many false negatives (up to 46% of trees with scats were missed) where koala densities are lower (Woosnam-Merchez et al. 2012; Jiang et al. 2012; Jiang et al. 2019; Witt et al. 2020). Any interpretation of SAT data must therefore be considered in the context of koala population density and landscape characteristics.

Under certain circumstances, higher koala activity levels likely indicate higher koala abundance (e.g. Phillips and Callaghan 2011; Ellis et al. 2013). However, absolute abundance cannot be estimated using the SAT due to a combination of confounding factors. These include that scats are more readily detected at sites with simple substrates (Sullivan et al. 2004; Cristescu et al. 2012) and where koala densities are higher (Jiang et al. 2019), scat deposition rates vary between populations (Ellis et al. 2013), and environmental factors affect scat decay rates (Sullivan et al. 2004; Rhodes et al. 2011; Cristescu et al. 2012). Phillips and Callaghan (2011) also proposed a series of threshold activity levels that could be used to differentiate between sites with low, medium, or high use by koalas. They suggested that areas with low levels of activity (taking koala population density into account) were likely to be due to transitory individuals. The validity of this assumption, however, has not been tested in the peer-reviewed scientific literature, and Phillips and Callaghan (2011) cautioned that 'any activity in areas occupied by naturally occurring, low density populations should be regarded as ecologically meaningful for conservation and management purposes until proven otherwise.'

A more recent refinement of the SAT is rapid-SAT, which further restricts searches to 1) trees greater than 30 cm dbh, and 2) species considered to be preferred koala food trees (Phillips et al. 2021). When utilising rapid-SAT, searches are discontinued either when a faecal pellet is located within a plot or after 5 to 7 preferred koala food trees have been sampled (Phillips et al. 2021). The method cannot be used to determine activity levels, but can identify habitat use by koalas in some situations (Phillips et al. 2021). However, surveys using rapid-SAT did not detect koalas at several locations at which they were detected using passive acoustics (B Law 2021, pers. comms.). There is no critical evaluation in the peer-reviewed literature of whether the restrictions imposed by rapid-SAT create a survey bias that increases the rate of false negative detections. However, that is a strong possibility given that koalas are known to use trees below 30 cm dbh, and that they can live in areas that are dominated by regrowth after heavy timber harvesting (Law et al. 2018). There may also be significant issues associated with the process of selecting preferred koala food trees for the SAT and rapid-SAT method at some locations. Some

practitioners who use SAT methods consider a relatively small number of tree species 'preferred' despite larger lists being recommended by state governments based on expert consultation (e.g. OEH 2018). In addition, the diets of koalas in many areas are poorly understood and it is not always possible to generalise food preferences from one area to another. For example, *Eucalyptus viminalis* is a major component of the diet of koalas at Cape Otway, Victoria and in many other areas (Brice et al. 2019), but it is eaten relatively little by koalas in the NSW Monaro region (Lane et al. unpublished data, Blyton et al. unpublished data). Targeting *E. viminalis* in the Monaro and overlooking commonly browsed species in that region, like *E. rossii*, would be likely to increase false negative detections.

Koala rapid assessment method (KRAM)

The koala rapid assessment method (KRAM) is a modification of the SAT and was developed to address some of the SAT limitations (Woosnam-Merchez et al. 2012). Specifically, the KRAM advocates random selection of the central tree to remove the possibility of bias, and allows search effort to be directed under the whole tree canopy. It also allows search time to be customised for each survey to optimise scat detectability (Woosnam-Merchez et al. 2012).

One disadvantage of the KRAM is that it may be impractical for human observers to search under entire tree canopies over large areas (Jiang et al. 2019), although this issue may be somewhat alleviated when using well trained koala scat detection dogs (Cristescu et al. 2015; Cristescu et al. 2019b). Also, the KRAM guidelines for determining search effort per tree are not precise. This means that search times are subjective, which could make replication and comparison of findings between surveys difficult (Jiang et al. 2019).

Balanced koala scat survey (BKSS)

The balanced koala scat survey (BKSS) combines elements of both the SAT and KRAM to improve accuracy and practicality in the field (Jiang et al. 2019). The BKSS maintains the 1 m search radius around tree bases from the SAT, but incorporates the random selection of a central tree from the KRAM. Another difference is that the BKSS proposes that all 30 trees within a plot should be searched with no time limit, until the searcher either finds a single scat or they are satisfied that a thorough search has been conducted, such that a scat would likely have been located if present (Jiang et al. 2019). The unlimited search time is likely to increase the time taken to complete surveys using the BKSS method relative to the SAT, but it also increases the probability of detecting scats. For example, Jiang et al. (2019) found that it took more than 2 mins to detect the first scat under 14% to 46% of trees depending on koala activity levels and substrate. As a consequence, the BKSS produced less false negatives than the SAT, particularly in areas with low koala activity levels (Jiang et al. 2019). It also took up to 10 min to thoroughly search the ground around trees under which scats were not detected, with the total search time being influenced by the type of ground cover (Jiang et al. 2019).

Faecal standing crop method

The faecal standing crop method is a technique for estimating animal abundance (or density) from faecal pellet abundance. All faecal pellets within a specified area (e.g. under trees or along a specified transect) are counted, and koala density is estimated based on the known number of pellets produced per koala per day, the probability of detection, and the rate of scat decomposition or approximate pellet age (Sullivan et al. 2004; Seabrook et al. 2011; McGregor et al. 2013). These factors can vary between locations and seasons (Sullivan et al. 2002; Sullivan et al. 2004; Rhodes et al. 2011; Cristescu et al. 2012; Ellis et al. 2013). It is therefore critical that

they are determined at the site of interest, because different values can lead to vastly different density estimates (Sullivan et al. 2004; Ellis et al. 2013).

Trained scat detection dogs

Dogs that are specifically trained to detect koala scat can be integrated into standard scat search methods to improve the probability of scat detection, reduce search time (that is, improve efficiency), and increase the effective survey area (Cristescu et al. 2015; Cristescu et al. 2019a; Cristescu et al. 2020). All of these factors reduce the likelihood of false negatives, and increase confidence that scat survey results can be used to develop appropriate management and offset strategies (Cristescu et al. 2015). Other more casual methods can also be employed to take advantage of a dog's strengths, such as allowing the dog to follow a scent trail, or positioning the search area to benefit from wind direction (Cristescu et al. 2020). These latter methods are most appropriate when the purpose of a survey is to demonstrate occupancy, rather than to determine activity levels (Cristescu et al. 2020).

Although dogs offer a promising option for relatively rapid surveys, accuracy and efficiency are likely to vary between dog and handler teams (Reindl-Thompson et al. 2006), and also be affected by environmental factors (Cristescu et al. 2020). For example, the accuracy of koala scat detections by dogs is affected by whether a dog is worked on or off leash, as well as by wind and temperature (Cristescu et al. 2015; Cristescu et al. 2020). Dense understorey may also impede access for dogs. Dog and handler teams should be regularly monitored and tested under different conditions to check performance and assess potential bias (e.g. the handler's behaviour and beliefs can lead to false positives), and to document whether performance exceeds that of alternative survey methods (Cristescu et al. 2020). Other issues with the use of detection dogs are the potential to disturb wildlife, which can be difficult to assess (Cristescu et al. 2020). Detection dogs are also unsuitable to use in areas where predator control baits have been deployed.

Genetic sampling from faecal pellets

DNA extracted from single koala faecal pellets can be used to distinguish between individuals and determine their sex (Wedrowicz et al. 2013; Wedrowicz et al. 2017b; Wedrowicz et al. 2017a; Schultz et al. 2018), and can also provide data on genetic diversity within populations (Wedrowicz et al. 2018). It may also be possible to capture information about the eucalypt species eaten and the presence of diseases, such as Chlamydia pecorum and specific parasites, during DNA analysis of koala scat (Schultz et al. 2018). For environmental impact assessments, genetic analysis may be particularly useful where there is a need to identify the number of unique individuals sampled in an area during scat surveys.

Genetic sampling is best undertaken using fresh faecal pellets (e.g. less than 2 days old). As koala faecal pellets age, there is a decline in the amount and quality of DNA that can be extracted, although some pellets up to 4 weeks old can still be used for genotyping when stored appropriately (Wedrowicz et al. 2013; Schultz et al. 2018). Genetic studies may benefit from utilising dogs that are specifically trained to detect fresh koala scat (Schultz et al. 2018). Other limitations are that DNA yields are lower when koala scats are stored in paper bags prior to analysis, and when they have been exposed to wet conditions (Wedrowicz et al. 2013).

Theoretically, genotyping data can be used to estimate population size if sampling strategies are designed for mark-recapture analysis. A specific consideration is that there must be well-defined criteria for what constitutes an independent sample from the same individual (e.g. spatial

and/or temporal separation) so that capture probabilities can be estimated (Arandjelovic and Vigilant 2018). In addition, a sufficient number of samples must be collected, which may be difficult when surveys are undertaken in small areas, short timeframes, or low-density populations. There are currently no published studies on the use of genetic census methods in koalas, but genetic estimates of population size in other cryptic species have been shown to be reasonably precise, and more accurate than estimates from other indirect survey methods (Arandjelovic and Vigilant 2018). A major disadvantage of genetic sampling, however, is the need for specialised analytical services that can be costly.

6.2.2 Call playback

Standard call playback surveys involve broadcasting a recording of a male koala bellowing, while observers listen for responses from other males that may be in the vicinity (e.g. Jurskis et al. 2001). To optimise detection, call playback surveys should be conducted at night during the breeding season, and in the absence of strong winds or rain (Jurskis et al. 2001). Playback surveys have typically been used to improve occupancy estimates in low density populations where other survey techniques are inefficient at demonstrating koala presence. For example, systematic regional surveys recorded only 14 koalas over 2 decades in south-eastern NSW, whereas call playback surveys recorded 14 individuals in one season (Jurskis et al. 2001).

It should be noted that koalas do not always bellow in response to call playbacks (Mitchell 1990), so these playback surveys are likely to underestimate koala occupancy and/or abundance, especially since they only detect males. For example, Jurskis et al. (2001) reported that koalas were not recorded during call playback surveys in some areas where they were known to occur. Advances in technology mean that passive acoustic surveys have tended to replace call playback in recent times.

6.2.3 Passive acoustics

Passive acoustic surveys utilise sound recorders that can be placed at strategic locations within a defined study area. Male koalas make distinctive bellowing sounds that are recognisable on the recordings through manual or automated processing (Hagens et al. 2018; Law et al. 2020). Sound recorders are generally inexpensive, and have been shown to be particularly effective at detecting koalas in sites that are difficult to survey by other methods, or where they occur in low densities (Law et al. 2018; Law et al. 2020). Law et al. (2020) also demonstrated that the number of person hours involved in surveying koalas via acoustic recordings (including data processing) was substantially lower than for scat surveys using the SAT, and that acoustic surveys returned slightly higher occupancy rates in the areas evaluated. The latter finding may be due to the fact that acoustic sampling allows detections over a larger area than scat surveys (e.g. 300 m radius of call recordings relative to 1 m radius around 30 trees for scat surveys) (Law et al. 2020).

Some of the limitations of passive acoustics include the fact that females and non-bellowing males (e.g. sub-adults) are not usually detected (although see Hagens et al. 2018), and that the rate of calling is strongly influenced by season, time of day and daily weather conditions. For example, bellowing predominantly occurs in the first half of the night during the breeding season, the timing of which can vary slightly between locations, but normally spring to early summer (Ellis et al. 2011; Hagens et al. 2018; Law et al. 2018; Law et al. 2020). Passive acoustic surveys are not recommended outside of the breeding season. Bellowing rates are also lower on warmer nights and during rain events or strong winds (Ellis et al. 2011; Hagens et al. 2018; Law et al. 2011; Hagens et al. 2018; Law et al. 2011; Hagens et al. 2018; Law

number of days for which acoustic data is collected. Law et al. (2020) estimated that a minimum of 4 to 5 nights was required to achieve a 90 to 95% probability of detecting calls at occupied sites, and this increased to 99% after 7 nights. Finally, acoustic data provides no additional information on, for example, the trees used by koalas, which can be obtained from many other survey methods.

It is not possible to estimate absolute koala abundance from acoustic data obtained from individual recording units. However, Hagens et al. (2018) reported that bellow occurrence was higher at sites with higher koala densities. More recent research suggests that male koala densities estimated from acoustic data collected from multiple recorders placed in a grid array were reasonably well correlated with density estimates from genetic analysis of faecal pellets (Law et al. 2021). It is therefore possible that acoustic arrays may become a more widely accepted method for estimating koala densities in the future.

6.2.4 Landscape nutritional quality surveys

Building on pioneering work that demonstrated a relationship between landscape use by koalas, population density and eucalypt browse nutritional quality (e.g. Moore et al. 2010), Au (2018) looked at the relationship between eucalypt nutritional quality and koala densities across 75 sites that included large parts of the koalas range from QLD, NSW, Victoria and South Australia. The research found that in landscapes where koalas are present, a substantial amount of the variation in koala density between sites can be explained by eucalypt nutritional quality (Au 2018). In addition, Au et al. (2019) found that increasing the proportion of browse trees with lower nutritional quality decreased the likelihood of koalas occurring in a landscape. The models developed for that research have been trialled as a method to assess koala habitat and predict koala densities in 2 separate studies that are currently ongoing. Preliminary results compared to other methods conducted in the same areas, including koala scat detection dogs in combination with scat DNA analysis and passive acoustics, are encouraging because they demonstrate considerable agreement (Marsh et al. unpublished data). However, linking koala density and habitat quality to field measures of eucalypt foliage nutritional quality is an area that requires additional research to validate this approach in more areas and independently from the original research. Given the extensive body of work that has focused on understanding the chemical determinants of diet selection by the koala, which are outlined in previous sections of this review, this method holds considerable promise for helping to measure and quantify habitat quality for the koala and potentially predict koala densities. However, current methods are relatively time consuming and require highly specialised skills and equipment.

Table 1 Benefits and limitations of commonly used direct methods to survey koalas, and their utility for determining presence and
density/abundance

Method	Uses and benefits	Limitations	Presence	Density/abundance
Transect – strip transects	 Predominantly used to count the number of koalas within a specified area Does not require highly specialised skills or resources Best suited for medium to high density populations 	 Substantial time and personnel required, which limits the scale at which the method can be applied Likely to obtain little data and many false absences in low density populations Density estimates must be corrected for the known rate of missed observations, but this can be difficult to quantify 	Yes, in medium to high density populationsª	Yes, if corrected for the rate of missed observations a,b
Transect – distance sampling or double observer	 Can estimate probability of koala detection, which improves abundance estimates Fewer personnel required than for strip transects Best suited for medium to high density populations 	 Requires experienced personnel – inexperienced observers may not see all koalas on the transect line, which violates an important assumption for abundance analysis Unsuited to small or low-density populations because a minimum number of sightings (60-80) are required to estimate detectability Potential high rate of false absence in low density populations 	Yes, in medium to high density populations a	Yes, if enough koalas are sighted to estimate detection probability a,c
Point surveys	 Can be undertaken at the same time and locations as scat surveys May provide similar abundance estimates to transect surveys in high density populations Only suitable for medium to high density populations 	• Low detection rates and high rates of false negatives in low density populations lead to large underestimates of abundance	Yes, in medium to high density populations d	Possibly in high density populations, but not with lower densities d,e,f

Method	Uses and benefits	Limitations	Presence	Density/abundance
Spotlighting (usually transect)	 Often used in conjunction with standardised transect methods (e.g. strip transects or distance sampling) Does not require highly specialised skills or resources Eye shine can increase detectability of koalas relative to diurnal searches 	 Some areas may not be suitable to survey at night Rate of detectability is still low, producing false negatives and underestimating density, especially in low density populations Observer bias possible if there are large differences in the detection capabilities/experience of observers Subject to the same limitations for estimating abundance as the sampling method it is paired with 	Yes, in medium to high density populations. Better than daytime transects in lower density populations g	Yes, if used in conjunction with appropriate sampling strategies g
Koala detection dogs	 Improve efficiency and detectability for locating koalas in locations that are accessible to dogs and handlers Can be used in conjunction with other standardised methods for abundance estimates 	 Requires specialised equipment and training There are few trained dogs/handlers No published literature quantifying benefits and limitations Must be used in conjunction with appropriate sampling strategies to produce density estimates, and subject to the same limitations 	Yes, when dogs are properly trained and conditions are suitable for this type of survey	Yes, if used in conjunction with appropriate sampling strategies
Thermal detection drones	 Thermal drone surveys can cover larger areas more thoroughly and efficiently than ground-based methods Higher rates of koala detection compared to other methods improves the likelihood of detecting presence, and density estimates Suitable for use in low density populations 	 Requires specialised equipment and training Detection of thermal signature requires sufficient temperature difference between koala and environment Results may not be directly comparable between sites due to differences in detectability Probability of detection is not known in many habitats Potential for false or duplicate detections which can inflate abundance estimates Different image processing methods can give different results 	Yes, when conditions are appropriate for surveys and the drone operator is experienced f,h	Yes e

Method	Uses and benefits	Limitations	Presence	Density/abundance
Mark-resight or mark- recapture	 Useful when a population census is required because abundance estimates are reasonably precise Potential to gather additional information about individuals (e.g. sex, health, age) Best suited for medium to high density populations 	 Requires experienced personnel Labour intensive and can be costly More invasive to the animals than techniques that do not require capture 	Yes c	Yes c
Radio or GPS tracking	 Can demonstrate whether individuals are resident or transitory Home range sizes may correlate with population density Can gather additional information about individuals, including their sex, health, reproductive state, age, tree species preferences, and rates and causes of mortality Can be used in low density populations 	 Requires specialised equipment and experienced personnel Labour intensive, time consuming and costly More invasive to the animals than techniques that do not require capture To calculate density, enough individuals must be tracked and for sufficient time to understand home range overlap Koalas can move large distances, so radio tracking may not be practical without consent from surrounding landholders 	Yes, however, if radio tracking or GPS are used then presence is required, since koalas must be in a landscape to track	Yes, if enough individuals are tracked and home range overlap is known c
Camera traps	 Incidental images can demonstrate that koalas are present Can be used in a targeted manner to confirm that indirect evidence (e.g. claw marks, bark chewing, or scats) is due to koalas No specialised skills required 	 Koalas are not attracted to baits, so detections are usually incidental Koalas may not be detected even when they are present Not recommended as a primary survey method 	As secondary confirmation rather than as a primary search method i	No

a Dique et al. 2003b; b Dique et al. 2004; c Crowther et al. 2021; d Phillips and Callaghan 2014; e Phillips et al. 2007; f Witt et al. 2020; g Wilmott et al. 2019; h Corcoran et al. 2019; i Au et al. 2017.
Table 2 Benefits and limitations of commonly used indirect methods to survey koalas, and their utility for determining presence and density/abundance

Method	Uses and Benefits	Limitations	Presence	Density/ Abundance
Scats – SAT, RGB-SAT, or rapid-SAT	 Often used to establish koala presence and/or activity levels Well-established methods that can be readily followed by inexperienced personnel Reduced time, cost and resources relative to some other search methods Best suited for medium to high density populations 	 Scat detectability can be low, producing many false negatives, particularly in low density populations Search is limited to within 1 m of tree trunk, but scat may be deposited anywhere under the canopy The strict search time does not allow for differences in detection rates between strata Results are not necessarily comparable between sites due to differences in detectability Surveys are usually targeted towards trees or habitats expected to be used by koalas, which generates a confirmation bias 	Yes, but false negatives are common a, b	No, although activity levels may be higher in higher density populations c
Scats – KRAM	 Addresses some of the SAT method limitations Random selection of focal tree to remove subjectivity Search area can include whole canopy Sampling effort can be customised depending on likely scat detectability 	 More time consuming than SAT methods due to increased search time and/or area Lack of precision in the guidelines about how to predetermine search effort may lead to lack of consistency between surveys 	Yes, but false negatives are possible, particularly in low density populations d	No, although strike rate may be higher in higher density populations e
Scats – BKSS	 Incorporates aspects of both SAT and KRAM, with modifications Random selection of focal tree to remove subjectivity Thorough search within 1 m radius of trunk without time restriction to account for differences in substrate and potential search area Improves likelihood of detecting scat in areas with low koala activity levels 	 Search restricted to within 1 m of tree trunk increases risk of false negatives More time consuming than SAT methods, especially in areas with low koala activity 	Yes, but false negatives are possible, particularly in low density populations b	No, although strike rate may be higher in higher density populations b

Method	Uses and Benefits	Limitations	Presence	Density/ Abundance
Scats – faecal standing crop method	 Can be used to estimate density/abundance Best suited to medium to high density populations 	 Requires intensive search effort May be of limited use in low density populations Must know the number of pellets produced per koala per day, the probability of detection, and the rate of scat decomposition or approximate pellet age for the location of interest 	Yes, although presence is required for this method	Yes, if factors that affect scat deposition and decay are known for the site f, g, h
Scats – detection dogs	 Increases survey area and search efficiency relative to other scat search methods Scat detectability improved in areas with difficult substrate Significantly reduced rate of false negatives 	 May provide limited data in low density populations Difficult for dogs to access areas with dense undergrowth Dogs may not be allowed in protected areas or areas that have been recently baited 	Yes d	No, although strike rate may be higher in higher density populations
Scats – genetic sampling	• Generally used in conjunction with other standard scat survey methods to provide additional information on the number of unique individuals of each sex	 Scats must be reasonably fresh Requires specialised processing that can be costly Information may not be particularly useful if few scats are collected, such as in a low-density population 	Yes, if scats are fresh i, j	Potentially – has been used in other species k
Call playback	 Can determine whether there are any responding males in the vicinity of the call Simple to undertake 	 Can only be undertaken during breeding season Only detects adult males who respond to the call Potential to disrupt natural behaviour if the call is perceived as a threat Probability of detection not known 	Yes, if a response is heard I. No response does not mean absence	No
Passive acoustics	• May be particularly useful for detecting koalas in low density populations	Data can only be collected during breeding seasonPrimarily detects adult males who are actively bellowing	Yes m, n	Yes, if using arrays o , otherwise no

Method	Uses and Benefits	Limitations	Presence	Density/ Abundance
	 Little experience required for deployment Additional data on the spatial arrangement of individuals can be obtained using carefully designed arrays 	Requires post-collection processing using specialised software		
Habitat nutritional analyses	 No need to detect koalas or koala signs Can provide information on the palatability of trees in the area and their likely contribution to the diet of local koalas. 	 Requires specialised equipment and trained personnel Methodology based on recent research that has not been widely applied for management purposes 	No	Can estimate density if koalas are present p, q

a Phillips and Callaghan 2011; b Jiang et al. 2019; c Ellis et al. 2013; d Cristescu et al. 2015; e Woosnam-Merchez et al. 2012; f Sullivan et al. 2004; g Seabrook et al. 2011; h McGregor et al. 2013; i Wedrowicz et al. 2013; j Schultz et al. 2018; k Arandjelovic and Vigilant 2018; l Jurskis et al. 2001; m Hagens et al. 2018; n Law et al. 2018; o Law et al. 2020; p Au 2018; q Au et al. 2019.

7 Review of commonly used koala habitat assessment criteria

7.1 Soil fertility

Key points:

- The relationship between soil fertility and eucalypt nutritional quality is not consistent in the peer-reviewed literature and neither is the relationship between soil fertility and koala abundance.
- There is a strong genetic component to browse nutritional quality that is not clearly linked to soil chemistry.
- For these reasons, soil fertility should not be used as an indicator of koala habitat or habitat quality.

Soil fertility is often used as an indicator of potential habitat quality, since fertile soils are thought to result in more nutritious browse for herbivores. In reality, this conventional thinking does not always hold true. Early landscape-scale research conducted in a few forest types in south-eastern Australia by Braithwaite et al. (1984) found a correlation between soil nutrients, leaf nutrients and habitat quality for arboreal folivores. While Braithwaite's hypothesis regarding links between foliar nutritional quality and habitat quality for eucalypt folivores has gained support as our understanding of the chemical determinants of browse quality have improved, the same cannot be said for the relationship between soil chemistry and leaf nutritional quality across landscapes. Although a few species of eucalypts grown under controlled glasshouse conditions have responded to higher soil fertility with more palatable browse (e.g. McArthur et al. 2003), other studies have found that leaves from eucalypts growing in more fertile soil become less palatable because they produce more herbivore deterrent plant secondary metabolites (PSMs) (e.g. Gleadow and Woodrow 2002; Moore et al. 2004b).

There is a perception that soil fertility influences the presence and abundance of koalas, but results are often mixed (e.g. McAlpine et al. 2007) or even find a negative correlation between soil fertility and koala occurrence/abundance (McAlpine et al. 2007; Callaghan et al. 2011; Law et al. 2017). Importantly, some of the highest nutritional quality browse measured across the range of the koala and the highest density koala populations can be found in forests and woodlands growing on low fertility, skeletal podsolised soils and solodic soils derived from sand (Moore et al. 2004a; Au 2018). This is not to say that high density koala populations always equate to healthy koala habitat (e.g. Whisson et al. 2016), but to demonstrate that the link between soil fertility and leaf nutritional quality is not consistent or required to support high koala reproductive success and large numbers of koalas. Landscapes previously overlooked as good koala habitat, in part because of their rocky, low fertility soils, are now known to support healthy and growing koala populations (e.g. the Monaro region of NSW).

Most knowledge about plant mineral nutrition comes from studies of agricultural crops that evolved from disturbance adapted species that proliferated in nutrient-rich conditions. These plants were then selectively bred for even greater productivity in high nutrient environments, and there was no selective pressure for efficient nutrient use. The links between soil fertility, plant productivity and leaf nutrient status typically follow the expected pattern in these systems, which is a high response rate to nutrient supply (Chapin 1980). This relationship is what many people think about when discussing links between soil fertility and plant productivity. However, plants that have evolved independently from artificial selection, and especially those that evolved in low-nutrient conditions can show very different responses to variations in soil fertility. In both high and low-fertility systems, root absorption capacity plays a key role in nutrient uptake and this capacity is largely driven by the genetics of the plant (Chapin 1980). In low-fertility systems, root absorption rates are typically very slow because the plants have evolved for efficient nutrient use rather than rapid uptake. As a consequence, plants adapted to low-fertility environments usually grow more slowly, but their concentration of foliar nutrients can be as high as plants growing in areas with higher nutrient availability (Chapin 1980). In both cases, absolute concentrations of foliar nutrients are determined largely by the genetics that dictate uptake by the plant in combination with environmental availability. This includes interactions between multiple soil elements that can vary at fine scales and limit or facilitate the uptake of other elements. In addition, plant associations with nitrogen fixing fungi and bacteria can further influence nutrient cycling beyond the confines of geochemistry.

Since there is such a strong genetic component to plant nutrient uptake and therefore concentrations of foliar nutrients in leaves, it is possible to have 2 neighbouring eucalypt trees of the same species on the same soil that have very different foliar concentration of the key mobile nutrients. The differences are often even greater across species that may occur in the same environment and grow side-by-side but have very different foliar chemistry. Phenotypic variation within and between species combined with local adaptation mean that the relationship between soil fertility and eucalypt foliar chemistry is not the simple pattern that might be expected from agricultural crops or even wild species that evolved in highly-fertile soils. Extending the relationship from soil fertility to the nutritional quality of eucalypt leaves for folivores like the koala is further complicated by the fact that the digestibility of plant proteins, which are measured by foliar nitrogen concentrations, are influenced by some PSMs that bind to proteins and make them less available to the animals. These PSMs and others that can be toxic are also strongly influenced by plant genetics (Andrew et al. 2005) and are the primary determinants of what and where koalas eat. An extreme example of this is a mosaic tree in which one branch has a different gene expression to the rest of the tree such that the leaves on that branch contain higher concentrations of herbivore deterrent PSMs and are not browsed, whereas the rest of the tree is less defended and over-browsed (Padovan et al. 2013, Figure 2). A single tree exposed to one set of environmental conditions can have leaves on different branches with different gene expression resulting in distinct chemotypes, which have very different nutritional quality and palatability to folivores. This demonstrates how little influence soil can have over plant-animal interactions.



Figure 2 A mosaic Eucalyptus sideroxlyon tree in NSW

Credit: © Penny Edwards and Wolf Wanjura.

There may be scales or specific landscape types in which soil fertility can directly link to both eucalypt leaf foliar chemistry and nutritional quality for the koala, but this may be the exception for this widely distributed folivore. It is also possible that more consistent links between soil fertility and eucalypt nutritional quality may become apparent when measures of soil fertility capture what is actually available to the plant. Soil nutrient concentrations are rough approximations of vegetation nutrient supply, since most soil nutrient stocks are unavailable in recalcitrant forms in natural systems (Aerts and Chapin 1999). Current methods for assessing soil fertility are often crude, highly variable and may rely on indicators rather than direct measurements at scales relevant to the trees in the landscape. Ultimately, the processes that drive eucalypt nutritional quality are multifaceted, and more research is required before soil fertility based on any measure can be pronounced a driver of koala presence and abundance. Importantly, correlation is not causation, and this is especially evident when patterns in one area do not agree with patterns in another. The inconsistency in the relationship between soil fertility and eucalypt nutritional quality across wide areas, within and between tree species and between different forest types in Australia, mean that, as a general rule, soil fertility should not be used as an indicator of koala habitat or koala habitat quality.

7.2 Tree size and age classes

Key points:

- Koalas regularly use trees across a wide range of sizes.
- Most studies of koala habitat and landscape use include trees ≥ 10 cm dbh.
- Smaller trees are often preferred for feeding at night and larger trees for resting during the day.
- Assessments that apply tree size thresholds larger than 10 cm dbh may overlook potential koala habitat or inappropriately devalue koala habitat that may be good quality
- The contribution of specific tree sizes classes to koala habitat quality is largely uncertain.

Some studies have found that koalas prefer smaller trees to feed in at night than they use in the day when they are primarily resting (e.g. Marsh et al. 2014a). Other studies focusing on daytime tree use or observations of koala scat have found that koalas use larger trees more often than smaller trees (e.g. Callaghan et al. 2011). Although koalas regularly utilise and feed in trees across a wide range of size classes, the significant relationship in these studies is due to the distribution of any tree with a koala observation being shifted towards larger trees during the daytime and smaller trees at night (Marsh et al. 2014a). The data from these studies does not provide information on the minimum or maximum size of tree required for koala habitat, since the koalas in those studies regularly use trees ranging in size from young regrowth that barely supports a koala's weight to the largest, old growth trees in a forest.

Most studies that investigate landscape use by koalas include any tree ≥ 10 cm dbh (Callaghan et al. 2011; Phillips and Callaghan 2011). Given that koalas and their scat are routinely found in association with trees in this 10 cm dbh size category, assessments that apply tree size thresholds larger than 10 cm dbh may overlook potential koala habitat or inappropriately devalue koala habitat that may be good quality. Importantly, studies that have investigated difference in nutritional quality between large and small trees have found either no relationship to tree size or that larger trees are less palatable than small trees (Moore et al. 2010; Marsh et al. unpublished data).

There are often differences in the nutritional quality of juvenile phase leaves (including epicormic regrowth), young adult phase leaves and mature adult phase leaves (Gras et al. 2005; Marsh et al. 2018); however, both large and small trees can have young and old leaf age classes or only one age class. Where a larger tree receives more visits than a smaller tree, it is likely due to the fact that they represent a larger food patch that accounts for a greater proportion of the available foliar biomass in a given area rather than any feeding requirement relating to tree size (Moore and Foley 2005). However, large trees may be important in some landscapes for thermoregulation due to their effects on local microclimates, greater canopy cover and larger thermal mass (Briscoe et al. 2014). Even if larger trees are important for habitat quality and/or carrying capacity in some areas, smaller trees would likely have current and increasing future value as koala habitat. More research is required before we understand how and when trees of various age classes constrain koala habitat or habitat quality across the range of this widely distributed species. The published literature does not include data that can be used to identify specific tree size thresholds that would be consistent across the range of the koala or even within a specific KMB.

7.3 Primary and secondary food tree species

Key points:

- Categories like 'primary' and 'secondary' food tree species overlook within species variation in nutritional quality and may not represent the contribution of tree species to koala diets in a local area.
- Trees from some species are more likely to be consistently highly palatable than trees from other species, but exceptions are not that unusual.
- It is important to value local information on koala feeding preferences because trees and koala populations can be physiologically different in different areas.
- Habitat assessments that rank the importance of particular eucalypt tree species as 'primary' or 'secondary' can overlook habitat or skew the collection of data because they don't accurately capture the trees that contribute the most to local koala population diets.

It has long been recognised that koalas are often associated with specific tree species or tree species assemblages (Lunney et al. 1998; White 1999; Phillips and Callaghan 2000; Adams-Hosking et al. 2012). In response to this, the terms primary and secondary food tree species are often used to classify trees species according to direct or indirect observations of koalas utilizing those tree species more often than other tree species (Pahl and Hume 1990; Phillips and Callaghan 2000). However, koalas are notoriously 'fussy eaters' and often refuse foliage from tree species that they typically prefer (Pahl and Hume 1990; Moore and Foley 2000), or paradoxically, preferentially browse on species that are not typically considered important koala food trees (Blyton et al. 2019; L Wilmott 2021, pers. comms.; K Marsh 2021, pers. comms.; D de Villers 2021, pers. comms.). Over the past 3 decades, extensive research has been undertaken to understand the drivers of diet selection by koalas and other eucalypt folivores. That work has identified key herbivore deterrent PSMs that vary both within and between tree species and dictate the palatability of eucalypt foliage (Moore et al. 2010; Marsh et al. 2021).

The terms primary and secondary are often used to rank koala food tree species, which are then used to inform koala habitat rankings, without knowing the actual nutritional quality of the trees in that landscape or the feeding preferences of koalas in the local area, which can differ across landscapes and populations (Pahl and Hume 1990; Blyton et al. 2019). Concepts like 'primary' and 'secondary' tree overlook the natural variability within and between tree species and can wrongly identify some trees as good food trees based on their species alone even though they may have a less palatable chemotype and vice versa. That said, trees from some species are more likely to be consistently highly palatable than trees from other species, but exceptions are not that unusual, and it is common to find less palatable trees from species that are usually highly palatable (Moore et al. 2005; Marsh et al. 2019). At sufficiently high foliar concentrations of certain PSMs, koalas will eat less or even refuse to browse from trees, regardless of whether those trees are from a 'primary' food tree species (Figure 3). Similarly, tree species that are typically considered less preferred 'secondary' browse often have chemotypes that make them more palatable than some locally available 'primary' food tree species and may comprise the majority of a koala's diet in that landscape.

It is important to value local information on koala diets because, in addition to variation in tree chemistry, koala populations can be physiologically different, allowing them to specialise on

local eucalypt species. Actual feeding observations of koalas and/or nutritional analyses may be needed to understand what trees are important food trees in a particular area. Using scat or tree occupancy observations alone to identify important food tree species could results in listing trees as 'primary or secondary' that actually make up a very small proportion of the diet in a given area (e.g. Tun 1993; Hasegawa 1995; Melzer 1995, K Marsh 2021, pers. comms.). From a management perspective, in many cases, all we have are tree lists based on expert opinions of what tree species are important browse for the koala based on indirect evidence, but these lists should be updated as new evidence is acquired. Methods of habitat assessment that rank the importance of particular eucalypt tree species as 'primary' or 'secondary' should be used with caution and awareness of limitations. They may overlook important habitat or skew the collection of data because they don't accurately capture the trees that are contributing the most to local koala population diets.

Figure 3 Koala food intake in relation to variable foliar concentrations of formylated phloroglucinol compounds from individual trees within a single tree species (*Eucalyptus viminalis*)



Source: adapted from Marsh et al. 2007. Note DM = dry matter, FPCs = Formylated phloroglucinol compounds.

7.4 Proportion of preferred food trees in a landscape (primary and secondary habitat)

Key points:

- There is no agreement in the literature about how many preferred food trees are needed in the landscape to support a koala population, and the true amount likely differs across the koala's range due to variation in nutritional quality and biomass
- The terms 'primary' and 'secondary' habitat should not be taken as an indication of actual habitat value or koala population densities.
- Recent research has found that there is often a poor relationship between assessment rankings of koala habitat and actual koala distributions and abundance
- Natural heterogeneity in koala habitat quality may be important for the long-term sustainability of koala populations.

A single koala food tree in a landscape would not be sufficient to support a koala, let alone a population of animals. However, the number or proportion of food trees necessary for a landscape to be considered koala habitat is an area of much speculation and disagreement in the literature. This is reflected by the fact that there are many different koala habitat assessment methods, and most of them use different thresholds of food tree numbers/proportions in a landscape to identify and rank koala habitat (Mitchell et al. 2021). In reality, the proportion of food trees required for a landscape to provide koala habitat and/or support a population of koalas is probably not consistent across the koala's range because it would depend in part on the quality of food that the available trees provide, as well as their size.

The Koala Habitat Information Base Technical Guide uses a single threshold of $\geq 15\%$ food trees to be considered potential koala habitat and has no primary or secondary habitat ranking (DPIE 2019), and this is probably the most precautionary approach across the various methods. The EPA (2016) has 3 habitat class rankings that are determined by thresholds of $\geq 30\%$ food trees for first class ranking, $\geq 15\%$ but less than 30% for a second class ranking, or less than 15% for third class habitat. Other habitat quality assessment methods further divide food trees themselves into primary and secondary or 'supplementary' food species. Those food tree classes are then used to determine habitat quality by the proportion that each class contributes to the landscape (e.g. DECC 2008; Phillips and Callaghan 2011).

To determine the proportion of trees in a landscape, some methods use stem counts based on the entire canopy (e.g. OEH 2014; EPA 2016; DPIE 2019), while others are based on stem counts from the overstory only (e.g. DECC 2008; Phillips and Callaghan 2011). Notably, there are also differences across the various methods in terms of what constitutes primary and secondary feed trees. Sometimes, additional criteria are also included in habitat rankings, such as a requirement for medium to high nutrient soils for primary habitat (Phillips et al. 2019), or rankings that consider whether vegetation is remnant or regrowth (Cristescu et al. 2019b).

Perhaps not surprising given the inconsistencies in assessing habitat quality and questionable relationships between existing thresholds and actual habitat requirements, recent research has found that there is often a poor relationship between assessment rankings of koala habitat and actual koala distributions and abundance (Cristescu et al. 2019b; Mitchell et al. 2021). This could

be due to koalas squeezing into ever smaller remaining habitat, regardless of quality, or a failure of current assessment methods to accurately identify and assess koala habitat. It is likely that both situations are contributing to the current mismatch between habitat assessments and landscape use by koalas.

Adding to this complexity is the fact that landscapes are naturally heterogenous and it is common to have both 'high' and 'low' quality habitat occurring in close proximity and intermixed in a mosaic. The scale of some habitat mapping, as well as subsampling landscapes for field surveys, may overlook pockets of higher quality habitat that contribute to the overall carrying capacity of the larger landscape. This natural heterogeneity is likely to be important for the long-term sustainability of koala populations as well. Conserving only areas with the highest carrying capacity can lead to overcrowding, over-browsing, and may increase disease transmission due to stress (Timms 2005; Whisson et al. 2016). In addition, lower quality habitat may be important for maintaining genetic diversity and connectivity, particularly in fragmented landscapes (Wiegand et al. 2005; Rhodes et al. 2008; Lollback et al. 2018). For these reasons, assigning higher value to 'primary' habitat than 'secondary' habitat, even if those categories could be determined from existing assessment methods, fails to recognise the important and potentially necessary contribution that habitat of variable quality contributes to the long-term sustainability of koala populations. If secondary habitat can support a koala population, even at a lower density, it should not automatically receive lower priority for conservation than an area of primary habitat. In addition, the designation of primary and secondary should not be taken as an indication of actual habitat value, or even carrying capacity, given the large discrepancies in assigning habitat value across methodologies and a growing body of research showing that these methods often do not align with where koalas are found (Cristescu et al. 2019b).

7.5 Tree species diversity

Key point:

• Koala habitat is not dependent on forest tree species diversity per se, but the quality of food and shelter the forest or woodland provides.

Koala populations can persist in natural monocultures and plantations dominated by single tree species. Koalas do not require diverse forests if the tree species present provide sufficient quality and quantity of food and shelter. There may be some forest types where a diversity of tree species is important for koalas to be able to meet their nutritional requirements from the trees available (Smith 2004). However, in other landscapes and in captivity, all, or nearly all of a koala's diet and other structural habitat requirements can be provided by a single tree species (Moore and Foley 2000; Sluiter et al. 2002; Brice et al. 2019). Tree species diversity should not be considered a requirement for koala habitat unless it has been robustly demonstrated that it is important for koala populations in a specific area. It is important to remember that it is the nutritional quality of the trees available, not the diversity of tree species per se, that drives foraging decisions and to a large degree, population densities. However, if koalas are introduced to a novel landscape (e.g. through translocation), a higher diversity of potential food trees may allow the new koalas to find a suitable diet that can sustain them given their particular experience, physiology, and microbiome, but this requires more research to confirm (M Blyton 2021, pers. comms.).

7.6 Remnant vegetation and non-remnant vegetation

Key points:

- Koala habitat should not be downgraded on the basis that it is regrowth rather than undisturbed.
- Assessments of koala habitat quality that rank regrowth vegetation as lower quality than undisturbed vegetation are poor predictors of actual koala landscape occupancy.

Both remnant vegetation (undisturbed) and non-remnant vegetation (formerly cleared) can be high quality koala habitat. There are situations in which restored landscapes may provide suboptimal habitat that act as sinks and increase mortality (e.g. revegetated road verges) (Osawa 1989; Battin 2004). However, when Cristescu et al. (2013) compared koala body condition, diet, predation risk and vegetation characteristics in rehabilitated (formerly mined) areas and undisturbed areas, they found no evidence that the rehabilitated areas provided lower quality habitat for the koala than the undisturbed landscape. A review of the value of regrowth forests to forest fauna in fragmented agricultural landscapes found that they can make valuable contributions to wildlife conservation and are important to the recovery of many species (Bowen et al. 2007). Since the koala is not dependent on very old, hollow bearing trees, it has the potential to use much younger regrowth than other hollow-dependent marsupial eucalypt folivores, like the greater glider.

Non-remnant habitat can be consistent with the definition of koala habitat within Commonwealth Guidelines (2014), but some state governments consider non-remnant regrowth to have less ecological value and this influences environment impact assessments for the koala when ranking 'habitat quality' (Cristescu et al. 2019b). Research in SE Queensland found that assessments of koala habitat quality that rank regrowth vegetation as lower quality than remnant vegetation are poor predictors of actual koala landscape occupancy patterns (Cristescu et al. 2019b). Koalas were just as likely to occur in areas of the landscape that were considered lower quality as they were in areas that were considered high quality (Cristescu et al. 2019b). Non-remnant vegetation should be given the same consideration as remnant vegetation when determining whether it is koala habitat and its potential utility to koalas should not be downgraded simply on the basis of whether the vegetation has regrown or has never been disturbed.

8 Locally important koala trees in the koala management bioregions

The tables in this section list LIKT and ancillary habitat trees for each Koala Management Bioregion for the listed koala. Source references for the trees in the lists are provided in Appendix B. These lists should be updated as knowledge about LIKT and ancillary habitat trees is refined and more information becomes available. Some western and central KMBs in QLD and NSW include large areas with little to no data on koala tree use. In these data-poor areas, trees that are listed as LIKT or ancillary habitat trees in adjacent KMBs may be similarly important to koalas. However, the KMB lists are based primarily on data about tree use in a particular KMB, and a tree species may not be listed if there is not sufficient data on its 'local' use.

8.1 Brigalow Belt

Tree species scientific name	Common name	Source
Eucalyptus brownii	Brown's box, Red river box	7
Eucalyptus camaldulensis	River Red Gum, Murray red gum, Yarrow	7,8
Eucalyptus chloroclada	Baradine gum, Red gum, Dirty gum	7, 24
Eucalyptus conica	Fuzzy box, Fuzzy gum	7
Eucalyptus coolabah	Coolibah, Coolabah	1, 3, 7, 8
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	7, 24
Eucalyptus drepanophylla	Queensland grey ironbark, Narrow-leaved ironbark	7, 19
Eucalyptus dura	Ironbark	1, 3, 7
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	1, 3, 7
Eucalyptus fibrosa	Broad-leaved red ironbark, Blue-leaved ironbark, Dusky- leaved ironbark	7, 24
Eucalyptus laevopinea	Silvertop stringybark	7
Eucalyptus largiflorens	Black box, Flooded box, River box	7
Eucalyptus longirostrata	Grey Gum	7
Eucalyptus major	Queensland grey gum, Grey gum	7
Eucalyptus melanophloia	Silver-leaved Ironbark	1, 3, 7, 8, 24
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	7
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	7,9
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	1, 7, 8
Eucalyptus orgadophila	Mountain Coolibah, Gum topped box	1, 3, 7, 9
Eucalyptus populnea	Poplar gum, Bimble box	1, 3, 7, 8, 9, 24
Eucalyptus punctate	Grey gum, Grey iron gum, Long-capped grey gum	7
Eucalyptus saligna	Sydney blue gum, Blue gum	7
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	7
Eucalyptus tereticornis	Forest red gum, Flooded gum, Queensland blue gum	1, 3, 7, 9

Table 3 Brigalow Belt Locally important koala trees

Tree species scientific name	Common name	Source
Acacia harpophylla	Brigalow, Spearwood, Orkor	7,9
Acacia salicina	Cooba, Motherumba, Broughton willow, Sally Wattle	9
Acacia tephrina	Boree	7
Corymbia citriodora	Lemon-scented gum, Spotted gum	1, 3, 7, 9
Corymbia dallachiana	Dallachy's ghost gum	1, 3, 7, 9
Corymbia erythrophloia	Red bloodwood, Variable-barked bloodwood, Red-barked bloodwood, Gum-topped bloodwood	1, 3, 7
Corymbia intermedia	Pink bloodwood, Red bloodwood	7
Corymbia tessellaris	Moreton Bay ash, Carbeen	1, 3, 7, 9
Eucalyptus acmenoides	White Mahogany, Narrow-leaved white stringybark	7, 24
Eucalyptus baileyana	Bailey's Stringybark, Black stringybark	7
Eucalyptus cambageana	Dawson River blackbutt, Dawson's gum, Coowarra box	1, 3, 7, 9
Eucalyptus decorticans	Gum-top Ironbark	7, 24
Eucalyptus platyphylla	White Gum, Poplar gum	7, 24
Eucalyptus thozetiana	Thozet's box, Mountain yapunyah	7, 8, 24
Melaleuca bracteata	Black tea-tree, River tea-tree, Mock olive	1, 3, 9

Table 4 Brigalow Belt Ancillary habitat trees

8.2 Central NSW Coast

Table 5 Central NSW Coast Locally important koala trees

Tree species scientific name	Common name	Source
Angophora costata	Sydney red gum, Rusty gum	11, 12, 13, 19
Eucalyptus albens	White Box	11, 12
Eucalyptus beyeriana	Beyer's ironbark	11, 12, 13
Eucalyptus blakelyi	Blakely's red gum, White budded gum	11, 12
Eucalyptus bosistoana	Coast grey box, Bosistos box, Gippsland grey box	11, 12, 13
Eucalyptus botryoides	Bangalay, Southern mahogany	11, 12, 13
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	11, 12
Eucalyptus canaliculata	Brown grey gum, Large fruited grey gum	11, 12
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	11, 12, 13
Eucalyptus cypellocarpa	Monkey gum, Small fruited mountain gum, Spotted mountain grey gum	11, 12, 13, 25
Eucalyptus dealbata	Baradine gum, Tumbledown red gum, Hill red gum	12
Eucalyptus deanei	Round-leaved gum, Deane's gum, Mountain blue gum	12, 13
Eucalyptus elata	River peppermint, River white gum	13, 25
Eucalyptus fibrosa	Broad-leaved red ironbark, Blue-leaved ironbark, Dusky- leaved ironbark	11, 12, 13
Eucalyptus globoidea	White stringybark	11, 12, 13, 25
Eucalyptus grandis	Flooded gum, Rose gum, Scrub gum	11, 12

Tree species scientific name	Common name	Source
Eucalyptus largeana	Craven grey box	11, 12
Eucalyptus longifolia	Woollybutt	11, 12, 13
Eucalyptus mannifera	Brittle gum, Red spotted gum, Mountain spotted gum	13, 25
Eucalyptus melliodora	Yellow box, Honey box, Yellow ironbox	11, 12
Eucalyptus microcorys	Tallowwood	11, 12, 13
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	11, 12, 13
Eucalyptus oblonga	Narrow-leaved stringybark, Sandstone stringybark	11, 12, 13, 25
Eucalyptus paniculata	Grey ironbark, Bloodwood	11, 12, 13
Eucalyptus parramattensis	Parramatta red gum, Drooping red gum	11, 12, 13
Eucalyptus piperita	Sydney peppermint, Urn-fruited peppermint	11, 12, 13
Eucalyptus propinqua	Grey gum, Small-fruited grey gum	11, 12, 13
Eucalyptus punctata	Grey gum, grey iron gum, Long-capped grey gum	11, 12, 13, 25
Eucalyptus quadrangulata	White-topped box, Coastal white box	11, 12, 13, 25
Eucalyptus racemosa	Narrow-leaved scribbly gum, Snappy gum, Scribbly gum	11, 12
Eucalyptus radiata	Narrow-leaved peppermint	13, 25
Eucalyptus resinifera	Red mahogany, Red messmate	11, 12, 13
Eucalyptus robusta	Swamp mahogany, Swamp messmate	11, 12, 13
Eucalyptus saligna	Sydney blue gum, Blue gum	11, 12, 13
Eucalyptus scias	Large-fruited red mahogany	11, 12, 13
Eucalyptus sclerophylla	Hard-leaved scribbly gum	11, 12, 13, 25, 30
Eucalyptus signata	Peppermint-leaved white gum, Scribbly gum	12
Eucalyptus tereticornis	Forest red gum, Blue gum, Flooded gum, Queensland blue gum	11, 12, 13, 25
Eucalyptus viminalis	Rough-barked ribbon gum, Manna gum, Ribbon gum	11, 12, 13, 25

Table 6 Central NSW Coast Ancillary habitat trees

Tree species scientific name	Common name	Source
Allocasuarina littoralis	Black she-oak, Bull oak	11, 12, 13
Allocasuarina torulosa	Forest oak, Rose she-oak	11, 12, 13
Angophora bakeri	Narrow-leaved apple, Small-leaved apple	11, 12, 13
Angophora floribunda	Apple, Rough-barked apple	11, 13
Casuarina glauca	Swamp oak, Guman	11
Corymbia eximia	Yellow bloodwood	11, 12, 13
Corymbia gummifera	Red bloodwood	11, 12, 13, 19
Corymbia maculate	Spotted gum, Spotted iron gum	11, 12, 13
Eucalyptus acmenoides	Narrow-leaved white stringybark, White mahogany	11, 12, 13
Eucalyptus agglomerate	Blue-leaved stringybark	11, 12, 13, 25, 26
Eucalyptus amplifolia	Cabbage gum, Cadagi	11, 12, 13
Eucalyptus bridgesiana	Apple gum, Apple box, Moonbi apple box	13

Tree species scientific name	Common name	Source
Eucalyptus camfieldii	Camfield's stringybark	11, 12
Eucalyptus capitellata	Brown stringybark	11, 12, 13
Eucalyptus carnea	Broad-leaved white mahogany, Thick-leaved mahogany	11, 12, 13
Eucalyptus consideniana	Yertchuk, Prickly stringybark, Pricklybark	11, 12, 13
Eucalyptus eugenioides	Thin-leaved stringybark, Wilkinson's stringybark, White stringybark	11, 12, 13
Eucalyptus glaucina	Slaty red gum	11, 12
Eucalyptus haemastoma	Broad-leaved scribbly gum	11, 12, 13
Eucalyptus imitans	Illawarra stringybark	11, 12, 13
Eucalyptus macrorhyncha	Red stringybark	11, 12, 13
Eucalyptus michaeliana	Hillgrove gum, Brittle gum	11, 12, 13
Eucalyptus pilularis	Blackbutt	11, 12, 13, 23, 30
Eucalyptus siderophloia	Northern grey ironbark	11, 12, 13
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	11, 12, 13
Eucalyptus sieberi	Silvertop ash, Coast ash	11, 12, 13, 25, 30
Eucalyptus sparsifolia	Narrow-leaved stringybark	11, 12, 13
Eucalyptus squamosa	Scaly bark	11, 12, 13
Eucalyptus umbra	Bastard white mahogany, Broad-leaved white mahogany	11, 12, 13
Melaleuca quinquenervia	Broad-leaved paperbark	11, 12, 23
Syncarpia glomulifera	Turpentine, Red luster	11, 12, 13

8.3 Central Queensland Coast

Table 7 Central Queensland Coast Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus acmenoides	Narrow-leaved white stringybark, White mahogany	7
Eucalyptus andrewsii	New England blackbutt	7
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	7,24
Eucalyptus drepanophylla	Queensland grey ironbark, Narrow-leaved ironbark	1, 3, 7, 24
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	7
Eucalyptus fibrosa	Broad-leaved red ironbark, Blue-leaved ironbark, Dusky-leaved ironbark	7
Eucalyptus largiflorens	Black box, Flooded box, River box	7
Eucalyptus latisinensis	White mahogany	7
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	7
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	7
Eucalyptus platyphylla	White gum, Poplar gum	1, 3, 7, 24
Eucalyptus resinifera	Red mahogany, Red messmate	7
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	1, 3, 7

Tree species scientific name	Common name	Source
Allocasuarina littoralis	Black she-oak, Bull oak	7
Casuarina equisetifolia subsp. incana	Coastal she-oak, Horsetail she-oak	1, 3, 7
Corymbia citriodora	Lemon-scented gum, Spotted gum	7
Corymbia clarksoniana	Clarkson's bloodwood	1, 3, 7
Corymbia intermedia	Pink bloodwood, Red bloodwood	7
Corymbia tessellaris	Moreton Bay ash, Carbeen	7
Lophostemon confertus	Scrub box, Brush box, Queensland box, Brisbane box	7
Lophostemon suaveolens	Swamp box, Swamp mahogany, Swamp turpentine	7
Melaleuca leucodendra	Weeping paperbark, Long-leaved paperbark, White paperbark	1, 3
Melaleuca nervosa	Fibrebark	1, 3, 7

Table 8 Central Queensland Coast Ancillary habitat trees

8.4 Central and Southern Tablelands

Table 9 Central and Southern Tablelands Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus albens	White box	11, 12
Eucalyptus amplifolia	Cabbage gum, Cadagi	11, 12
Eucalyptus blakelyi	Blakely's red gum, White budded gum	11, 12, 13
Eucalyptus bosistoana	Coast grey box, Bosistos box, Gippsland grey box	11, 12
Eucalyptus bridgesiana	Apple gum, Apple box, Moonbi apple box	11, 12, 13, 28
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	11, 12
Eucalyptus conica	Fuzzy box, Fuzzy gum	11, 12
Eucalyptus cypellocarpa	Monkey gum, Small fruited mountain gum, Spotted mountain grey gum	11, 12, 13
Eucalyptus dalrympleana	Broad-leaved ribbon gum, Broad-leaved kindling bark, mountain gum	11, 12, 13
Eucalyptus dealbata	Baradine gum, Tumbledown red gum, Hill red gum	11, 12
Eucalyptus dives	Broad-leaved Peppermint, Blue peppermint	11, 12, 13
Eucalyptus elata	River peppermint, River white gum	11, 12
Eucalyptus eugenioides	Thin-leaved Stringybark, White stringybark, Wilkinson's stringybark	11, 12, 13
Eucalyptus globoidea	White stringybark	11, 12, 13
Eucalyptus goniocalyx	Long-leaved box, Olive-barked box, Bundy	11, 12, 13
Eucalyptus maidenii	Maiden's gum	11, 12
Eucalyptus mannifera	Brittle gum, Red spotted gum, Mountain spotted gum	11, 12, 13, 28
Eucalyptus melliodora	Yellow box, Honey box, Yellow iron box	11, 12, 13
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	11, 12
Eucalyptus nortonii	Long-leaved box, Mealy bundy	11, 12, 13
Eucalyptus pauciflora	Snow gum, White sally, Jounama snow gum,	11, 12, 13, 28

Tree species scientific name	Common name	Source
Eucalyptus piperita	Sydney peppermint, Urn-fruited peppermint	11, 12, 13
Eucalyptus polyanthemos	Red box	11, 12, 13
Eucalyptus punctate	Grey gum, Grey iron gum, Long-capped grey gum	11, 12, 13
Eucalyptus quadrangulate	White-topped box, Coastal white box	11, 12
Eucalyptus radiata	Narrow-leaved peppermint, Forth river peppermint	11, 12, 13
Eucalyptus rossii	Inland scribbly gum, Scribbly gum, Western scribbly gum	11, 12, 28
Eucalyptus rubida	Candlebark	11, 12, 13, 22, 28
Eucalyptus sclerophylla	Hard-leaved scribbly gum	11, 12, 30
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	11, 12
Eucalyptus viminalis	Rough-barked ribbon gum, Manna gum, Ribbon gum	11, 12, 13, 28

Table 10 Central and Southern Tablelands Ancillary habitat trees

Tree species scientific name	Common name	Source
Callitris endlicheri	Black cypress-pine, Mountain cypress-pine	13
Callitris glaucophylla	White cypress-pine	13
Eucalyptus agglomerate	Blue-leaved stringybark	11, 12, 13, 26
Eucalyptus fibrosa	Broad-leaved red ironbark, Blue-leaved ironbark, Dusky- leaved ironbark	11, 12
Eucalyptus macrorhyncha	Red stringybark	11, 12, 13, 19
Eucalyptus obliqua	Messmate stringybark, Australian oak, Brown-topped stringybark	11, 12, 13
Eucalyptus oblonga	Narrow-leaved stringybark, Sandstone stringybark	11, 12, 23
Eucalyptus paniculate	Grey ironbark, Bloodwood	11, 12
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	11, 12, 13
Eucalyptus sieberi	Silvertop ash, Coast ash	11, 12, 13, 30

8.5 Darling Riverine Plains

Table 11 Darling Riverine Plains Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus albens	White box	11, 12
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	11, 12
Eucalyptus chloroclada	Baradine gum, Red gum, Dirty gum	11, 12
Eucalyptus conica	Fuzzy box, Fuzzy gum	11, 12
Eucalyptus coolabah	Coolabah, Coolibah	11, 12
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	11, 12
Eucalyptus dealbata	Baradine gum, Tumbledown red gum, Hill red gum	11, 12
Eucalyptus dwyeri	Dwyer's Red Gum, Dwyer's mallee gum	11, 12
Eucalyptus largiflorens	Black box, Flooded box, River box	11, 12
Eucalyptus melanophloia	Silver-leaved ironbark	11, 12

Tree species scientific name	Common name	Source
Eucalyptus melliodora	Yellow box, Honey box, Yellow ironbox	11, 12
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	11, 12
Eucalyptus populnea	Poplar box, Bimble box	11, 12
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	11, 12
Eucalyptus woollsiana	Narrow-leaved grey bark	11, 12

Table 12 Darling Riverine Plains Ancillary habitat trees

Tree species scientific name	Common name	Source
Callitris glaucophylla	White cypress pine	11,12

8.6 Desert Uplands

Table 13 Desert Uplands Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus brownii	Brown's box, Red river box	7
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	1, 3, 7
Eucalyptus coolabah	Coolabah, Coolibah	1, 3, 7
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	7
Eucalyptus drepanophylla	Queensland grey ironbark, Narrow-leaved ironbark	7
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	7
Eucalyptus melanophloia	Silver-leaved ironbark	7
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	7
Eucalyptus populnea	Poplar box, Bimble box	7
Eucalyptus thozetiana	Mountain Yapunyah, Thozet's box	7
Eucalyptus whitei	White's ironbark	1, 3, 7

Table 14 Desert Uplands Ancillary habitat trees

Tree species scientific name	Common name	Source
Acacia tephrina	Boree	1, 3, 7
Angophora costata	Sydney red gum, Rusty gum, Smooth-barked apple	7
Corymbia citriodora	Lemon-scented gum, Spotted gum	7
Corymbia trachyphloia	Brown bloodwood	7

8.7 Einasleigh Uplands

Table 15 Einasleigh Uplands Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus acmenoides	Narrow-leaved white stringybark, White mahogany	7, 24

Tree species scientific name	Common name	Source
Eucalyptus brownii	Brown's box, Red river box	7
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	7
Eucalyptus cambageana	Dawson river blackbutt, Dawson's gum, Coowarra box	7, 24
Eucalyptus coolabah	Coolabah, Coolibah	7
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	7, 24
Eucalyptus drepanophylla	Queensland grey ironbark, Narrow-leaved ironbark	7
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	7
Eucalyptus melanophloia	Silver-leaved ironbark	7
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	7
Eucalyptus orgadophila	Mountain Coolibah, Gum topped box	7
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	7
Eucalyptus whitei	White's ironbark	7

Table 16 Einasleigh Uplands Ancillary habitat trees

Tree species scientific name	Common name	Source
Acacia harpophylla	Brigalow, Spearwood, Orkor	7
Corymbia citriodora	Lemon-scented gum, Spotted gum	7
Corymbia intermedia	Pink bloodwood, Red bloodwood	7
Corymbia tessellaris	Moreton Bay ash, Carbeen	7
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	7
Eucalyptus platyphylla	White gum, Poplar gum	7

8.8 Far West NSW

Table 17 Far West NSW Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus albens	White box	11, 12, 13
Eucalyptus blakelyi	Blakely's red gum, White budded gum	11, 12
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	11, 12, 13
Eucalyptus chloroclada	Baradine gum, Red gum, Dirty gum	11, 12, 26
Eucalyptus coolabah	Coolabah, Coolibah	11, 12, 13
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	11, 12
Eucalyptus dealbata	Baradine gum, Tumbledown red gum, Hill red gum	11, 12
Eucalyptus largiflorens	Black box, Flooded box, River box	11, 12, 13
Eucalyptus melanophloia	Silver-leaved ironbark	11, 12, 13
Eucalyptus melliodora	Yellow box, Honey box, Yellow ironbox	11, 12, 13
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	11, 12, 13
Eucalyptus populnea	Poplar box, Bimble box	11, 12, 13
Eucalyptus woollsiana	Narrow-leaved grey box	11, 12

Tree species scientific name	Common name	Source
Angophora floribunda	Apple, Rough-barked apple	11, 12
Callitris glaucophylla	White cypress pine	11, 12, 13
Casuarina cristata	Belah, Muurrgu	11, 12
Eucalyptus intertexta	Inland red gum, Gum coolibah, Smooth-barked coolibah, Western red box	11, 13
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	11, 12
Geijera parviflora	Wilga	11, 12

Table 18 Far West NSW Ancillary habitat trees

8.9 Mitchell Grass Downs

Table 19 Mitchell Grass Downs Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	1, 3, 7, 8
Eucalyptus coolabah	Coolabah, Coolibah	1, 3, 7, 8
Eucalyptus melanophloia	Silver-leaved Ironbark	1, 3, 7, 8, 24
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	1, 7, 8
Eucalyptus populnea	Poplar box, Bimble box	1, 7, 8
Eucalyptus thozetiana	Mountain Yapunyah, Thozet's box	1, 7, 8

Table 20 Mitchell Grass Downs Ancillary habitat trees

Tree species scientific name	Common name	Source
Acacia harpophylla	Brigalow, Spearwood, Orkor	7
Acacia tephrina	Boree	3, 7
Corymbia tessellaris	Moreton Bay ash, Carbeen	7
Eucalyptus whitei	White's ironbark	3

8.10 Mulga Lands

Table 21 Mulga Lands Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	1, 7, 8, 10
Eucalyptus cambageana	Dawson river blackbutt, Dawson's gum, Coowarra box	1, 7, 17, 18
Eucalyptus chloroclada	Baradine gum, Red gum, Dirty gum	7
Eucalyptus coolabah	Coolabah, Coolibah	1, 7, 8, 17, 18
Eucalyptus decorticans	Gum-topped ironbark	1, 17
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	1, 7, 17, 18

Tree species scientific name	Common name	Source
Eucalyptus intertexta	Inland red gum, Gum coolibah, Smooth-barked coolibah, Western red box	1, 7, 17
Eucalyptus largiflorens	Black box, Flooded box, River box	7
Eucalyptus longifolia	Woollybutt	7
Eucalyptus melanophloia	Silver-leaved ironbark	1, 7, 8, 10, 18, 24
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	1, 17
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	1, 8, 17, 18
Eucalyptus orgadophila	Mountain Coolibah, Gum topped box	1, 17, 18
Eucalyptus populnea	Poplar box, Bimble box	1, 7, 8, 10, 17, 18
Eucalyptus thozetiana	Mountain Yapunyah, Thozet's box	1, 7, 8, 17, 18

Table 22 Mulga Lands Ancillary habitat trees

Tree species scientific name	Common name	Source
Acacia harpophylla	Brigalow, Spearwood, Orkor	1, 7, 17
Corymbia terminalis	Bloodwood, Desert Bloodwood, Western bloodwood, Inland bloodwood	1, 7, 17
Corymbia tessellaris	Moreton Bay ash	1, 7, 17, 18

8.11 North Coast NSW

Table 23 North Coast NSW Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus acmenoides	Narrow-leaved white stringybark, White mahogany	11, 12, 13, 21, 31
Eucalyptus amplifolia	Cabbage gum, Cadagi	11, 12, 13, 31
Eucalyptus bancroftii	Bancroft's red gum, Orange gum, Forest red gum, Tumbledown red gum	11, 12, 13, 31
Eucalyptus canaliculata	Brown grey gum, Large fruited grey gum	11, 12, 13
Eucalyptus eugenioides	Thin-leaved Stringybark, White stringybark, Wilkinsons stringybark	11, 12, 13, 31
Eucalyptus glaucina	Slaty red gum	11, 12, 13, 31
Eucalyptus globoidea	White stringybark	11, 12, 13, 21, 31
Eucalyptus grandis	Flooded gum, Rose gum, Scrub gum	11, 12, 13, 31
Eucalyptus laevopinea	Silvertop stringybark	11, 12, 13, 31
Eucalyptus largeana	Craven grey box	11, 12, 31
Eucalyptus microcorys	Tallowwood	11, 12, 13, 21, 31
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	11, 12, 13, 31
Eucalyptus parramattensis	Parramatta red gum, Drooping red gum	13, 31
Eucalyptus propinqua	Grey gum, Small-fruited grey gum	11, 12, 13, 21, 31
Eucalyptus punctata	Grey gum, Grey iron gum, Long-capped grey gum	11, 12, 13, 21, 31
Eucalyptus resinifera	Red mahogany, Red messmate	11, 12, 13, 31

Tree species scientific name	Common name	Source
Eucalyptus robusta	Swamp mahogany, Swamp messmate	11, 12, 13, 19, 21, 31
Eucalyptus saligna	Sydney blue gum, Blue gum	11, 12, 13, 31
Eucalyptus seeana	Narrow-leaved red gum	11, 12, 13, 31
Eucalyptus siderophloia	Northern grey ironbark	11, 12, 13, 31
Eucalyptus signata/racemosa	Narrow-leaved scribbly gum, Snappy gum, Scribbly gum	11, 12, 13, 19, 21, 31
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	11, 12, 13, 21, 31
Eucalyptus tindaliae	Ramornie stringybark, Tindale's stringybark	11, 12, 13, 31
Eucalyptus viminalis	Rough-barked ribbon gum, Manna gum, Ribbon gum	13

Table 24 North Coast NSW Ancillary habitat trees

Tree species scientific name	Common name	Source
Allocasuarina littoralis	Black she-oak, Bull oak	13, 31
Allocasuarina torulosa	Forest oak, Rose she-oak	11, 12, 13, 21
Alphitonia excelsa	Red ash	13
Angophora costata	Sydney red gum, Rusty gum, Smooth-barked apple	13, 21
Angophora floribunda	Apple, Rough-barked apple	11, 12, 13, 31
Callistemon salignus	Willow bottlebrush	13
Callitris columellaris	Coastal cypress-pine, Murray River cypress-pine, Northern cypress-pine	13
Casuarina glauca	Swamp oak, Guman	13
Corymbia gummifera	Red bloodwood	11, 12, 13, 31
Corymbia henryi	Large-leaved spotted gum	11, 12, 13, 31
Corymbia intermedia	Pink bloodwood, Red bloodwood	11, 12, 13, 31
Corymbia maculate	Spotted gum, Spotted iron gum	11, 12, 13, 31
Eucalyptus cameronii	Diehard stringybark	13
Eucalyptus campanulata	New England blackbutt, Gum-topped peppermint, New England ash	11, 12, 31
Eucalyptus capitellata	Brown's stringybark	13
Eucalyptus carnea	Broad-leaved white mahogany, Thick-leaved mahogany	11, 12, 13, 31
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	11, 12, 13
Eucalyptus fibrosa	Broad-leaved red ironbark	11, 12, 13, 31
Eucalyptus melliodora	Yellow box, Honey box, Yellow ironbox	13
Eucalyptus nobilis	Giant white gum, Forest ribbon gum	11, 12, 31
Eucalyptus pilularis	Blackbutt	11, 12, 13, 19, 21, 23, 31
Eucalyptus piperita	Sydney peppermint, Urn-fruited peppermint	13
Eucalyptus placita	Grey ironbark	11, 12, 13, 31
Eucalyptus planchoniana	Bastard tallowwood, Needlebark stringybark	11, 12, 13, 31
Eucalyptus psammitica	Broad-leaved white mahogany, Bastard white mahogany	11, 12, 13, 31

Tree species scientific name	Common name	Source
Eucalyptus quadrangulate	White-topped box, Coastal white box	13
Eucalyptus rummeryi	Steel box, Rummery's box	11, 12, 13, 31
Eucalyptus scias	Large-fruited red mahogany	11, 12, 31
Eucalyptus sieberi	Silvertop ash, Coast ash	23, 31
Eucalyptus umbra	Bastard white mahogany, Broad-leaved white mahogany	11, 12, 13, 31
Glochidion ferdinandi	Cheese tree	13
Lophostemon confertus	Scrub box, Brush box, Queensland box, Brisbane box	13
Lophostemon suaveolens	Swamp box, Swamp mahogany, Swamp turpentine	13
Melaleuca quinquenervia	Broad-leaved paperbark	11, 12, 13, 21, 23, 31
Syncarpia glomulifera	Turpentine, Red luster, Yanderra	13

8.12 New England Tablelands QLD

Table 25 New England Tablelands QLD Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus albens	White box	7, 11, 12, 13
Eucalyptus amplifolia	Cabbage gum, Cadagi	11, 12, 13
Eucalyptus banksii	Tenterfield woollybutt	7
Eucalyptus blakelyi	Blakely's red gum, White budded gum	7, 11, 12, 13
Eucalyptus bridgesiana	Apple gum, Apple box, Moonbi apple box	11, 12, 13
Eucalyptus caleyi	Caley's ironbark, Drooping ironbark	7, 11, 12, 13
Eucalyptus caliginosa	Broad-leaved stringybark, New England stringybark	7, 11, 12, 13
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	7, 11, 12, 13
Eucalyptus chloroclada	Baradine gum, Red gum, Dirty gum	11, 12, 13
Eucalyptus conica	Fuzzy box, Fuzzy gum	7, 11, 12
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	7, 11, 12, 13
Eucalyptus dalrympleana	Broad-leaved ribbon gum, Broad-leaved kindling bark, Mountain gum	7, 11, 12, 13
Eucalyptus dealbata	Baradine gum, Tumbledown red gum, Hill red gum	7, 11, 12, 13
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	11, 12
Eucalyptus fibrosa	Broad-leaved red ironbark, Blue-leaved ironbark, Dusky-leaved ironbark	7, 12
Eucalyptus laevopinea	Silvertop stringybark	7, 11, 12, 13
Eucalyptus melanophloia	Silver-leaved ironbark	7, 11, 12, 13
Eucalyptus melliodora	Yellow box, Honey box, Yellow ironbox	7, 11, 12, 13
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	7, 11, 12, 13
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	7, 11, 12, 13
Eucalyptus nova-anglica	New England peppermint, Black peppermint	11, 12, 13
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	7
Eucalyptus populnea	Poplar box, Bimble box	11, 12, 13

Tree species scientific name	Common name	Source
Eucalyptus prava	Orange gum, Moonbi red gum	7, 11, 12, 13
Eucalyptus punctate	Grey gum, Grey iron gum, Long-capped grey gum	7, 11, 12, 13
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	7, 11, 12, 13
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	7, 11, 12, 13
Eucalyptus williamsiana	William's stringybark, Large-leaved stringybark	11, 12, 13
Eucalyptus youmanii	Youman's stringybark	7, 11, 12, 13

Table 26 New England Tablelands QLD Ancillary habitat trees

Tree species scientific name	Common name	Source
Angophora floribunda	Rough-barked apple	7, 11, 12, 13
Angophora subvelutina	Apple	12, 13
Callitris glaucophylla	White cypress pine	7, 11, 12, 13
Corymbia citriodora	Lemon-scented gum, Spotted gum	7
Eucalyptus nobilis	Giant White Gum, Forest ribbon gum	7, 11, 12, 13

8.13 Northern Tablelands NSW

Table 27 Northern Tablelands NSW Locally important koala trees

Tree species scientific name	Common name	Source
Angophora subvelutina	Broad-leaved Apple	11, 12, 13
Eucalyptus acaciiformis	Wattle-leaved Peppermint	11, 12, 13
Eucalyptus albens	White box	11, 12, 13
Eucalyptus amplifolia	Cabbage gum, Cadagi	11, 12, 13
Eucalyptus blakelyi	Blakely's red gum, White budded gum	11, 12, 13
Eucalyptus bridgesiana	Apple gum, Apple box, Moonbi apple box	11, 12, 13
Eucalyptus brunnea	Round leaf gum	11, 12, 13
Eucalyptus caleyi	Caley's ironbark, Drooping ironbark	11, 12, 13
Eucalyptus caliginosa	Broad-leaved stringybark, New England stringybark	11, 12, 13
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	11, 12, 13
Eucalyptus dalrympleana	Broad-leaved ribbon gum, Broad-leaved kindling bark, Mountain gum	11, 12, 13
Eucalyptus dealbata	Baradine gum, Tumbledown red gum, Hill red gum	11, 12, 13
Eucalyptus laevopinea	Silvertop stringybark	11, 12, 13
Eucalyptus melliodora	Yellow box, Honey box, Yellow ironbox	11, 12, 13
Eucalyptus microcorys	Tallowwood	11, 12
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	11, 12, 13
Eucalyptus nicholii	Narrow-leaved peppermint, Willow peppermint	11, 12, 13
Eucalyptus pauciflora	Snow gum, White sally, Jounama snow gum,	11, 12, 13
Eucalyptus prava	Orange gum, Moonbi red gum	11, 12, 13
Eucalyptus punctate	Grey gum, Grey iron gum, Long-capped grey gum	12, 13

Tree species scientific name	Common name	Source
Eucalyptus radiata	Narrow-leaved peppermint	11, 12, 13
Eucalyptus saligna	Sydney blue gum, Blue gum	11, 12
Eucalyptus stellulata	Black sallee, Black sally, Muzzlewood	11, 12, 13
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	11, 12, 13
Eucalyptus viminalis	Rough-barked ribbon gum, Manna gum, Ribbon gum	11, 12, 13
Eucalyptus williamsiana	William's stringybark, Large-leaved stringybark	11, 12, 13
Eucalyptus youmanii	Youman's stringybark	11, 12, 13

Table 28 Northern Tablelands NSW Ancillary habitat trees

Tree species scientific name	Common name	Source
Allocasuarina littoralis	Black she-oak, Bull oak	11, 12, 13
Angophora floribunda	Apple, Rough-barked apple	11, 12, 13
Callitris glaucophylla	White cypress pine	11, 12, 13
Eucalyptus andrewsii	New England blackbutt	13
Eucalyptus campanulata	New England Blackbutt, Gum-topped peppermint, New England ash	11, 12, 13
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	11, 12
Eucalyptus eugenioides	Thin-leaved stringybark, Wilkinson's stringybark	11, 12
Eucalyptus macrorhyncha	Red stringybark	11, 12, 13
Eucalyptus melanophloia	Silver-leaved ironbark	11, 12, 13
Eucalyptus michaeliana	Hillgrove gum, Brittle gum	11, 12, 13
Eucalyptus nobilis	Giant white gum, Forest ribbon gum	11, 12, 13
Eucalyptus nova-anglica	New England peppermint, Black peppermint	11, 12, 13
Eucalyptus obliqua	Messmate stringybark, Australian oak, Brown-topped stringybark	11, 12 13
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	11, 12, 13

8.14 NSW South Coast

Table 29 NSW South Coast Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus bosistoana	Coast grey box, Bosistos box, Gippsland grey box	11, 12, 13
Eucalyptus cypellocarpa	Monkey gum, Small fruited mountain gum, Spotted mountain grey gum	11, 12, 13
Eucalyptus eugenioides	Thin-leaved Stringybark, White stringybark, Wilkinsons stringybark	11, 12
Eucalyptus globoidea	White stringybark	11, 12, 13
Eucalyptus longifolia	Woollybutt	11, 12, 13
Eucalyptus maidenii	Maiden's gum	11, 12, 13
Eucalyptus meulleriana	Yellow stringybark	11, 12, 13
Eucalyptus obliqua	Messmate stringybark, Australian oak, Brown-topped stringybark	11, 12, 13
Eucalyptus punctate	Grey gum, Grey iron gum, Long-capped grey gum	11, 12, 13

Tree species scientific name	Common name	Source
Eucalyptus saligna	Sydney blue gum, Blue gum	11, 12
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	11, 12
Eucalyptus tricarpa	Red Ironbark, Mugga ironbark	11, 12, 13
Eucalyptus viminalis	Rough-barked ribbon gum, Manna gum, Ribbon gum	11, 12, 13

Table 30 NSW South Coast Ancillary habitat trees

Tree species scientific name	Common name	Source
Allocasuarina littoralis	Black she-oak, Bull oak	11, 12, 13
Angophora floribunda	Rough-barked apple	11, 12, 13
Corymbia gummifera	Red bloodwood	11, 12, 13
Corymbia maculate	Spotted gum, Spotted iron gum	11, 12, 13
Eucalyptus agglomerate	Blue-leaved stringybark	11, 12, 13
Eucalyptus baueriana	Blue box, Round-leaved box	11, 12, 13
Eucalyptus consideniana	Yertchuk, Prickly stringybark, Pricklybark	11, 12, 13
Eucalyptus elata	River peppermint	11, 12, 13
Eucalyptus fastigata	Brown barrel, Cut-tail	11, 12, 13
Eucalyptus paniculate	Grey ironbark	11, 12
Eucalyptus pilularis	Blackbutt	11, 12
Eucalyptus piperita	Sydney peppermint	11, 12
Eucalyptus sclerophylla	Hard-leaved scribbly gum	11, 12
Eucalyptus sieberi	Silvertop ash, Coast ash	11, 12, 13

8.15 North West Slopes

Table 31 North West Slopes Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus albens	White Box	11, 12, 13
Eucalyptus blakelyi	Blakely's red gum, White budded gum	11, 12, 13
Eucalyptus caliginosa	Broad-leaved stringybark, New England stringybark	11, 12
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	11, 12, 13
Eucalyptus canaliculata	Brown grey gum, Large fruited grey gum	11, 12
Eucalyptus chloroclada	Baradine gum, Red gum, Dirty gum	11, 12, 13
Eucalyptus conica	Fuzzy box, Fuzzy gum	11, 12
Eucalyptus coolabah	Coolabah, Coolibah	11, 12, 13
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	11, 12, 13, 27
Eucalyptus dealbata	Baradine gum, Tumbledown red gum, Hill red gum	11, 12, 13
Eucalyptus dwyeri	Dwyer's Red Gum, Dwyer's mallee gum	11, 12
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	11, 12
Eucalyptus laevopinea	Silvertop stringybark	11, 12

Tree species scientific name	Common name	Source
Eucalyptus largiflorens	Black box, Flooded box, River box	11, 12
Eucalyptus melanophloia	Silver-leaved Ironbark	11, 12, 13, 19
Eucalyptus melliodora	Yellow box, Honey box, Yellow ironbox	11, 12, 13
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	11, 12, 13
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	11, 12
Eucalyptus parramattensis	Parramatta red gum, Drooping red gum	11, 12
Eucalyptus pauciflora	Snow gum, White sally, Jounama snow gum,	11, 12
Eucalyptus populnea	Poplar box, Bimble box	11, 12, 13
Eucalyptus prava	Orange gum, Moonbi red gum	11, 12
Eucalyptus punctata	Grey gum, Grey iron gum, Long-capped grey gum	11, 12
Eucalyptus viminalis	Ribbon gum, Manna gum, Rough-barked ribbon gum	11, 12
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	11, 12
Eucalyptus woollsiana	Narrow-leaved grey box	11, 12, 13

Table 32 North West Slopes Ancillary habitat trees

Tree species scientific name	Common name	Source
Angophora floribunda	Rough-barked apple	11, 12, 13
Callitris glaucophylla	White cypress pine	11, 12, 13, 27
Casuarina cristata	Belah, Muurrgu	11, 12, 13, 27
Eucalyptus bridgesiana	Apple box, Apple gum, Moonbi apple box	11, 12
Eucalyptus caleyi	Drooping ironbark, Caley's ironbark	11, 12
Eucalyptus dalrympleana	Broad-leaved ribbon gum, Broad-leaved kindling bark, mountain gum	11, 12
Eucalyptus fibrosa	Broad-leaved red ironbark, , Blue-leaved ironbark, Dusky- leaved ironbark	11, 12
Eucalyptus goniocalyx	Bundy, Long-leaved box, Olive-barked box	11, 12
Eucalyptus macrorhyncha	Red stringybark	11, 12
Eucalyptus mannifera	Brittle gum, Red-spotted gum, Mountain spotted gum	11, 12
Eucalyptus nobilis	Giant white gum, Forest ribbon gum	11, 12
Eucalyptus polyanthemos	Red box	11, 12
Eucalyptus quadrangulate	White-topped box, Coastal white box	11, 12
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	11, 12, 13

8.16 Riverina

Table 33 Riverina Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	11, 12
Eucalyptus largiflorens	Black box, Flooded box, River box	11, 12
Eucalyptus melliodora	Yellow box, Honey box, Yellow ironbox	11, 12

Tree species scientific name	Common name	Source
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	11, 12
Eucalyptus populnea	Poplar box, Bimble box	11, 12

Table 34 Riverina Ancillary habitat trees

Tree species scientific name	Common name	Source
Callitris glaucophylla	White cypress pine	11, 12
Casuarina cristata	Belah, Muurrgu	11, 12
Eucalyptus albens	White box	11, 12
Eucalyptus intertexta	Gum coolibah, Gum-barked coolabah, Smooth-barked coolibah, Western red box	11, 12

8.17 South East QLD

Table 35 South East QLD Locally important koala trees

Tree species scientific name	Common name	Source
Corymbia citriodora	Lemon-scented gum, Spotted gum	1, 2, 4, 6, 14, 15, 19, 20
Corymbia henryi	Large-leaved spotted gum	1, 2, 15, 20
Eucalyptus acmenoides	Narrow-leaved white stringybark, White mahogany	1, 2, 4, 6, 7, 15
Eucalyptus andrewsii	New England blackbutt	2,7
Eucalyptus baileyana	Bailey's stringybark, Black stringybark	1, 2, 7, 15
Eucalyptus bancroftii	Bancroft's red gum, Orange gum, Forest red gum, Tumbledown red gum	1, 2
Eucalyptus brownii	Brown's box, Red river box	1, 2
Eucalyptus camaldulensis	River red gum, Murray red gum, Yarrow	1, 2
Eucalyptus campanulata	New England Blackbutt, Gum-topped peppermint, New England ash	1, 2, 7
Eucalyptus carnea	Broad-leaved white mahogany, Thick-leaved mahogany	1, 2, 6, 7, 15
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	1, 2, 6, 7, 14, 15, 16
Eucalyptus deanei	Round-leaved gum, Deane's gum, Mountain blue gum	6, 7
Eucalyptus decorticans	Gum-topped ironbark	1, 2, 7
Eucalyptus drepanophylla	Queensland grey ironbark, Narrow-leaved ironbark	1, 2
Eucalyptus dunnii	Dunn's white gum	1, 2
Eucalyptus dura	Ironbark	1, 2, 7, 15
Eucalyptus eugenioides	Thin-leaved Stringybark, White stringybark, Wilkinsons stringybark	1, 2
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	1, 2, 7, 19
Eucalyptus fibrosa	Broad-leaved red ironbark, Blue-leaved ironbark, Dusky-leaved ironbark	1, 2, 6, 7, 15

Tree species scientific name	Common name	Source
Eucalyptus grandis	Flooded gum, Rose gum, Scrub gum	1, 2, 4, 6, 7, 20
Eucalyptus hallii	Goodwood gum	1, 2, 24
Eucalyptus helidonica	Helidon white mahogany	1, 2, 7
Eucalyptus laevopinea	Silvertop stringybark	1, 2, 7
Eucalyptus latisinensis	White mahogany	1, 2, 7
Eucalyptus longirostrata	Grey gum	1, 2, 7
Eucalyptus major	Queensland grey gum, Grey gum	1, 2, 6, 7, 15
Eucalyptus melanophloia	Silver-leaved ironbark	1, 2, 6, 7, 14
Eucalyptus microcarpa	Grey box, Narrow-leaved box, Inland box	1, 2
Eucalyptus microcorys	Tallowwood	1, 2, 4, 6, 7, 15, 16
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	1, 2, 6, 7
Eucalyptus obliqua	Messmate stringybark, Australian oak, Brown- topped stringybark	1, 2, 7
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	7
Eucalyptus orgadophila	Mountain Coolibah, Gum topped box	1, 2
Eucalyptus planchoniana	Bastard tallowwood, Needlebark stringybark	1, 2, 3, 5, 7, 15
Eucalyptus populnea	Poplar box, Bimble box	1, 2, 7
Eucalyptus portuensis	White mahogany, Barayly	1, 2, 7
Eucalyptus propinqua	Small-fruited grey gum, Grey Gum	1, 2, 4, 6, 7, 15
Eucalyptus psammitica	Broad-leaved white mahogany, Bastard white mahogany	1, 2, 7
Eucalyptus punctate	Grey gum, Grey iron gum, Long-capped grey gum	1, 2, 7
Eucalyptus racemose	Narrow-leaved scribbly gum, Snappy gum, Scribbly gum	1, 2, 3, 4, 5, 6, 7, 15, 16, 20
Eucalyptus resinifera	Red mahogany, Red messmate	1, 2, 3, 4, 5, 6, 7, 15
Eucalyptus robusta	Swamp mahogany, Swamp messmate	1, 2, 3, 4, 5, 6, 7, 14, 16
Eucalyptus saligna	Sydney blue gum, Blue gum	1, 2, 6, 7
Eucalyptus seeana	Narrow-leaved red gum	1, 2, 6, 7, 15
Eucalyptus siderophloia	Northern grey ironbark	1, 2, 4, 6, 7, 20
Eucalyptus sideroxylon	Red ironbark, Mugga ironbark, Three-fruited red ironbark	1, 2
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	1, 2, 3, 4, 5, 6, 7, 14, 15, 16
Eucalyptus tindaliae	Ramornie stringybark, Tindale's stringybark	1, 2, 3, 6, 7, 15

Table 36 South East QLD Ancillary habitat trees

Tree species scientific name	Common name	Source
Allocasuarina littoralis	Black she-oak, Bull oak	1, 2, 4, 6, 7, 15
Allocasuarina torulosa	Forest oak, Rose she-oak	1, 2, 4, 6
Angophora leiocarpa	Rusty gum, Sydney red gum	1, 2, 5, 6, 7, 15
Angophora woodsiana	Smudgee	1, 2, 6, 7, 15

Tree species scientific name	Common name	Source
Banksia serrata	Saw banksia, Old-man banksia, Wiriyagan	1, 4
Callitris columellaris	White cypress-pine, Murray River cypress-pine, Northern cypress-pine	1, 2, 4, 5, 7
Corymbia intermedia	Pink bloodwood, Red bloodwood	1, 2, 4, 5, 6, 7, 14, 15, 16
Corymbia tessellaris	Moreton Bay ash, Carbeen	1, 2, 6, 7, 14
Eucalyptus albens	White box	1, 2
Eucalyptus cambageana	Dawson river blackbutt, Dawson's gum, Coowarra box	1, 2
Eucalyptus nobilis	Giant white gum, Forest ribbon gum	1, 2, 7
Eucalyptus pilularis	Blackbutt	1, 2, 3, 5, 6, 7
Eucalyptus umbra	Bastard white mahogany, Broad-leaved white mahogany	5
Lophostemon confertus	Scrub box, Brush box, Queensland box, Brisbane box	1, 2, 3, 4, 5, 6, 7, 14, 15, 20
Lophostemon suaveolens	Swamp box, Swamp mahogany, Swamp turpentine	1, 2, 4, 6, 7, 14, 15, 16
Melaleuca quinquenervia	Broad-leaved paperbark	1, 2, 3, 4, 6, 7, 15, 16
Syncarpia glomulifera	Turpentine, Red luster, Yanderra	1, 2, 4, 7

8.18 Wet Tropics

Table 37 Wet Tropics Locally important koala trees

Tree species scientific name	Common name	Source
Eucalyptus acmenoides	Narrow-leaved white stringybark, White mahogany	7
Eucalyptus crebra	Narrow-leaved ironbark, Narrow-leaved red ironbark, Muggago	7
Eucalyptus drepanophylla	Queensland grey ironbark, Narrow-leaved ironbark	7
Eucalyptus exserta	Queensland peppermint, Yellow messmate, Bendo	7, 19
Eucalyptus grandis	Flooded gum, Rose gum, Scrub gum	7
Eucalyptus moluccana	Coastal grey box, Gum-topped box, Grey box	7
Eucalyptus ochrophloia	Yapunyah, Napunyah, Yellow jacket	7
Eucalyptus resinifera	Red mahogany, Red messmate	7
Eucalyptus tereticornis	Forest red gum, Blue gum, Queensland blue gum	7, 19

Table 38 Wet Tropics Ancillary habitat trees

Tree species scientific name	Common name	Source
Corymbia citriodora	Lemon-scented gum, Spotted gum	7
Corymbia intermedia	Pink bloodwood, Red bloodwood	7
Corymbia tessellaris	Moreton Bay ash, Carbeen	7
Eucalyptus platyphylla	White gum, Poplar gum	7, 19
Eucalyptus portuensis	Mahogany	7, 19
Lophostemon confertus	Scrub box, Brush box, Queensland box, Brisbane box	7
Melaleuca quinquenervia	Broad-leaved paperbark	7

Appendix A: List of people who provided feedback

- Dr Alistair Melzer
- Dr Allen McIlwee
- Anthea Challis
- Dr Bill Ellis
- Dr Brad Law
- Dr Cathryn Dexter
- Chris Allen
- Chris Meakin
- Dr Claire Runge
- Emeritus Professor Clive McAlpine
- Adjunct Professor Dan Lunney
- Dr Deidre de Villiers
- George Madani
- Dr Harriet Preece
- Dr Ivan Lawler
- James Fitzgerald
- Dr Jennie Mallela
- Dr John Callaghan
- John Turbill
- Dr Jon Hanger
- Katie Johnston
- Lachlan Wilmott
- Lucy Porter
- Mark Aitkens
- Margot Law
- Associate Professor Mathew Crowther
- Dr Michaela Blyton
- Dr Nicole Gallahar
- Dr Rebecca Montague-Drake

- Rod Pietsch
- Dr Romane Cristescu
- Sarah Brown
- Simon Barber
- Dr Steven Cork
- Emeritus Professor William Foley

Appendix B: Reference sources for LIKT and ancillary habitat tree lists

Code	Citation
1	Runge, CA, Rhodes, JR and Lopez-Cubillos, DS 2021a, <u>Mapping koala habitat for greater Queensland: Koala</u> <u>tree list - TableA2</u> . Dataset. Threatened Species Recovery Hub. The University of Queensland, Brisbane, QLD.
2	DES 2020, <u>Spatial modelling for koalas in South East Queensland: Report version 1.1. Koala Habitat Areas</u> (<u>KHA</u>) v1.0, <u>Locally Refined Koala Habitat Areas (LRKHA) v1.1, Koala Priority Areas (KPA) v1.0, Koala</u> <u>Habitat Restoration Areas (KHRA) v1.0.</u> Department of Environment and Science, Queensland Government. Brisbane, QLD.
3	Melzer, A, Cristescu, R, Ellis, W, et al. 2014, <u>The habitat and diet of koalas (Phascolarctos cinereus) in</u> <u>Queensland</u> . Australian Mammalogy 36(2), pp. 189–199.
4	Callaghan, J, McAlpine, C, Thompson, J, et al. 2011, <u>Ranking and mapping koala habitat quality for</u> <u>conservation planning on the basis of indirect evidence of tree-species use: A case study of Noosa Shire,</u> <u>south-eastern Queensland.</u> Wildlife Research 38(2), pp. 89–102.
5	Woodward, W, Ellis, WA, Carrick, FN, et al. 2008, <u>Koalas on North Stradbroke Island: Diet, tree use and</u> <u>reconstructed landscapes.</u> Wildlife Research 35(7), pp. 606–611.
6	de Villiers, D 2021, Moreton bay rail project data on tree use 2013-2017.
7	Runge, C.A, Rhodes, JR and Lopez-Cubillos, DS 2021b, <u>Queensland Koala Habitat Mapping. RE sp. tree</u> <u>suitability appendix table1</u> . Dataset. Threatened Species Recovery Hub. The University of Queensland, Brisbane, QLD.
8	Wu, H, McAlpine, CA and Seabrook, LM 2012, <u>The dietary preferences of koalas, Phascolarctos cinereus, in</u> <u>southwest Queensland</u> . Australian Zoologist 36(1), pp. 93–102.
9	Ellis, WAH, Melzer, A, Carrick, FN, et al. 2002, <u>Tree use, diet and home range of the koala (Phascolarctos</u> <u>cinereus) at Blair Athol, central Queensland</u> . Wildlife Research 29(3), pp. 303–311.
10	Smith, AG, McAlpine, C, Rhodes, JR, et al. 2013, <u>At what spatial scales does resource selection vary? A case</u> study of koalas in a semiarid region. Austral Ecology 38(2), pp. 230–240.
11	SEPP 2021, <u>State Environmental Planning Policy (koala habitat protection) 2021</u> . NSW Department of Planning Industry and Environment, NSW Government. Sydney, NSW.
12	DPIE 2019, <u>Koala habitat information base technical guide</u> . Sydney: Department of Planning, Industry and Environment, NSW Government. Sydney, NSW.
13	OEH 2018, <u>A review of koala tree use across New South Wales</u> . Office of Environment and Heritage, State of NSW Government. Sydney, NSW.
14	Barth, BJ, FitzGibbon, SI, Gillett, A, et al. 2020, <u>Scattered paddock trees and roadside vegetation can</u> provide important habitat for koalas (Phascolarctos cinereus) in an agricultural landscape. Australian Mammalogy 42, pp. 194–203.
15	Lollback, GW, Castley, JG, Mossaz, AC, et al. 2018, <u>Fine-scale changes in spatial habitat use by a low-density</u> <u>koala population in an isolated periurban forest remnant</u> . Australian Mammalogy 40(1), pp. 84–92.
16	de Oliveira, SM, Murray, PJ, de Villiers, DL, et al. 2013, <u>Ecology and movement of urban koalas adjacent to</u> <u>linear infrastructure in coastal south-east Queensland</u> . Australian Mammalogy 36, pp. 45–54.
17	Sullivan, BJ, Norris, WM and Baxter, GS 2003, <u>Low-density koala (Phascolarctos cinereus) populations in</u> <u>the mulgalands of south-west Queensland.</u> II. Distribution and diet. Wildlife Research 30(4), pp. 331–338.
18	Sullivan, BJ, Baxter, GS and Lisle, AT 2002, <u>Low-density koala (Phascolarctos cinereus) populations in the mulgalands of south-west Queensland.</u> I. Faecal pellet sampling protocol. Wildlife Research 29(5), pp. 455–462.
19	Dr M. Blyton (2021), personal communication
20	Dr D. de Villiers (2021), personal communication

Code	Citation
21	Dr R. Montague-Drake (2021), personal communication
22	Dr K. Marsh (2021), personal communication
23	G. Madani (2021), personal communication
24	Dr A. Melzer (2021), personal communication
25	M. Law (2021), personal communication
26	Dr J. Callaghan (2021), personal communication
27	Prof. M. Crowther (2021), personal communication
28	J. Fitzgerald (2021), personal communication
29	Dr C. Allen (2021), personal communication
30	L. Willmott (2021), personal communication
31	J. Turbill (2021), personal communication

Note: Tree species scientific and common names were extracted from the following sources:

APNI 2021. Australian Plant Name Index [Accessed: 20 July 2021].

Brown, A.R., Guymer, G.P. and Jessup, L.W. 2020. <u>Census of the Queensland Flora 2020</u>. Queensland Department of Environment and Science: Brisbane, accessed 28/07/2021.

EUCLID 2021. Eucalypts of Australia [Accessed: 20 July 2021].

IBIS 2021. Integrated Botanical Information System [Accessed: 20 July 2021].

PlantNET 2021. The NSW Plant Information Network System [Accessed: 20 July 2021].

Tree species distributions were sourced from AVH 2021. Australasian Virtual Herbarium [Accessed: 20 July 2021].

Glossary

Term	Definition
Ancillary habitat element	Landscape elements such as commonly used shelter vegetation species and the ground that contribute to koala habitat when they co-occur with locally important koala trees (LIKT, see definition below).
ARKS	Areas of Regional Koala Significance
Barrier	Definition from the National Recovery Plan for the Koala (DAWE 2022): Impediments to the genetic dispersal of Koalas such that fewer than one individual capable of breeding can naturally move between populations over three generations. Barriers include geographic features such as escarpments or inhospitable landscapes but do not include structures such as roads where movement is possible even if irregular or results in an increased rate of mortality.
BKSS	Balanced Koala Scat Survey
Impediment	A natural or artificial landscape feature that interferes with the safe movement of koalas across a landscape, such as roadways.
Chemotype	A type of plant that has similar morphological characteristics to another plant (e.g. same species or subspecies) but differs in quantities and/or types of chemical components.
Corridor	A strip of habitat that connects 2 or more habitat patches. Corridors differ from the landscape that borders them on both sides, which is not habitat.
DAWE	Department of Agriculture, Water and The Environment (Commonwealth)
Dbh	Diameter at Breast Height
DECC	Department of Environment and Climate Change (NSW)
Digestible Nitrogen	An integrated measure of foliar nutritional quality that considers the influence of tannin-binding on the amount of nitrogen available for digestion by some herbivores.
DM	Dry Matter
DPIE	Department of Planning, Industry and Environment (NSW)
EPA	Environment Protection Authority (NSW)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
FPCs	Formylated Phloroglucinol Compounds
Formylated Phloroglucinol Compounds (FPCs)	A specific group of plant secondary metabolites found in some Eucalyptus species from the Symphyomyrtus subgenus known to influence the nutritional quality of browse and feeding by the koala.
Genotype	For the purpose of this document, a genotype refers to the genetic material (i.e. alleles) that determine a trait or a number of traits in an organism.
Habitat Connectivity	The connectedness of habitat patches, which is determined by whether a koala is able to move from one habitat patch to another without a barrier.
Habitat Degradation	A reduction in the quality of habitat that affects the survival, health and/or reproductive fitness of animals in that landscape and ultimately reduces the carrying capacity, or number of animals that a landscape can sustainably support.
Habitat Fragmentation	The subdivision of a large area of habitat into multiple smaller areas of habitat.
Habitat Loss	Loss of suitable conditions required for a species to be present in a landscape.
Habitat Patch	An area of habitat with all the necessary resources for the persistence of a population. A habitat patch can be isolated or connected to other habitat patches.
HR	Home Range
IBRA	Interim Biogeographic Regionalisation for Australia
A review of koala habitat assessment criteria and methods

Term	Definition
Koala Habitat	The biophysical environment required by a koala to survive and reproduce.
КМА	Koala Management Area
КМВ	Koala Management Bioregion
KMR	Koala Modelling Region
Koala Management Bioregion (KMB)	A management unit designated for the purpose of this document, consisting of delineated land areas within New South Wales and Queensland derived from Koala Modelling Regions and Queensland Bioregions in New South Wales (NSW) and Queensland (QLD), respectively.
KoRV	Koala Retrovirus
KRAM	Koala Rapid Assessment Method
LIKT	Locally Important Koala Trees
Locally Important Koala Trees (LIKT)	Trees from species that are regularly browsed by koalas in a particular KMB, such that it could be considered a substantial portion of the koalas' diet. Where data from feeding observations or nutritional quality is lacking, then the tree species must be associated with medium or high use by koalas from observations of animals in a tree or scat associations with trees in published literature or from direct feedback from local koala researchers and/or koala carers in the region. See section 3.2 for a more detailed definition.
Matrix	The land surrounding a habitat patch, which differs markedly in composition and/or structure and does not contain all the resources necessary for the persistence of a koala population.
Metapopulation	Definition from the National Recovery Plan for the Koala (2022): The set of biological populations within a larger area, where movement or gene flow from one biological population to at least some other patches is possible and is important for maintaining abundance and distribution at regional scale, even if such movement is infrequent
Monocalypt	Common name for eucalypt species from the <i>Eucalyptus</i> (formerly <i>Monocalyptus</i>) subgenus. This is the second largest eucalypt subgenus. Many trees from this subgenus produce a group of plant secondary metabolites called unsubstituted B-ring flavanones (UBFs), which are known to deter feeding by the koala if present in sufficient quantities.
Nutritional Quality	Used in reference to eucalypt browse in this document, nutritional quality refers to foliar concentrations of digestible nitrogen, which is a proxy for protein and a key limiting nutrient for the koala, and plant secondary metabolites that are known to influence palatability, feeding tree choice and population densities of the koala.
ОЕН	Office of Environment and Heritage (NSW)
Palatability	How much leaf an animal will eat (i.e. total intake of browse).
Plant Secondary Metabolites (PSMs)	Chemical compounds produced by a plant through metabolic pathways, which are not used for primary processes (i.e. growth and reproduction).
PSM	Plant Secondary Metabolite
Population	Definition from the National Recovery Plan for the Koala (DAWE 2022): A set of individuals that live in the same habitat patch and interact with one another, commonly forming a breeding unit within which the exchange of genetic material is more or less unrestricted.
Refugia	A habitat that provides spatial and/or temporal protection from one or more threats.
RGB-SAT	Regularised Grid Based-SAT
RPAS	Remotely Piloted Aircraft System
SAT	Spot Assessment Technique
SDM	Species Distribution Model
SEPP	State Environmental Planning Policy 2021 (NSW)

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Term	Definition
Source	Habitat in which birth rate typically exceeds the death rate of resident animals and young individuals frequently disperse to populate other areas.
Sink	Habitat in which the death rate typically exceeds the birth rate of resident animals and local populations only persist on the basis of immigration.
Species	Following the EPBC Act (s528), a species is a group of biological entities that (a) interbreed to produce fertile offspring; or (b) possess common characteristics derived from a common gene pool; and includes (c) a sub-species.
Stepping Stone	A relatively isolated, locally important koala tree or collection of trees in the matrix that contribute to functional connectivity between habitat patches and/or expand the area of useable habitat around a habitat patch. If a barrier separates a tree from a habitat patch, it cannot be a Stepping Stone, but a Stepping Stone can prevent distance between patches from becoming a barrier.
Symphyomyrtle	The common name for eucalypt species from the Symphyomyrtus subgenus. This is the largest eucalypt subgenus. Many trees from this subgenus make a group of plant secondary metabolites called formylated phloroglucinol compounds (FPCs), which are known to deter feeding by the koala if present in sufficient quantities.
Tannins	A common class of plant secondary metabolites found in many plants that can bind to foliar protein and make it unavailable for digestion.
Thermoregulation	An animal's regulation of body temperature.
Threat	A natural or anthropogenic process, activity or event that can negatively affect the survival, abundance or evolutionary potential of a species or ecological community.
UAV	Unmanned Aerial Vehicle
UBFs	Unsubstituted B-Ring Flavanones
Unsubstituted B-ring Flavanones (UBFs)	A specific group of plant secondary metabolites found in some <i>Eucalyptus</i> species from the <i>Eucalyptus</i> (formerly <i>Monocalyptus</i>) subgenus and known to influence the nutritional quality of browse and feeding by the koala.

References

Adams-Hosking, C, McAlpine, C, Rhodes, JR, et al. 2012, <u>Modelling changes in the distribution of the critical food resources of a specialist folivore in response to climate change</u>. Diversity & Distributions 18(9), pp. 847–860.

Aerts, R and Chapin, FS 1999, <u>The mineral nutrition of wild plants revisited: A re-evaluation of processes and patterns.</u> Fitter, A. H. and Raffaelli, D. G. eds. Advances in Ecological Research 30, pp. 1–67.

Andrew, RL, Peakall, R, Wallis, IR, et al. 2005, <u>Marker-based quantitative genetics in the wild?</u>: <u>The heritability and genetic correlation of chemical defenses in Eucalyptus</u>. Genetics 171(4), pp. 1989–1998.

Arandjelovic, M and Vigilant, L 2018, <u>Non-invasive genetic censusing and monitoring of primate</u> <u>populations</u>. American Journal of Primatology 80(3), p. e22743.

Ashman, KR, Rendall, AR, Symonds, MRE, et al. 2020, <u>Understanding the role of plantations in the</u> <u>abundance of an arboreal folivore.</u> Landscape and Urban Planning 193, p. 103684.

Ashman, KR, Watchorn, DJ and Whisson, DA 2019, <u>Prioritising research efforts for effective</u> <u>species conservation: A review of 145 years of koala research</u>. Mammal Review 49(2), pp. 189–200.

Au, J 2018, <u>Multi-scale effects of nutrition on an arboreal folivore</u>. PhD thesis. The Australian National University, Canberra.

Au, J, Clark, RG, Allen, C, et al. 2019, <u>A nutritional mechanism underpinning folivore occurrence</u> <u>in disturbed forests.</u> Forest Ecology and Management 453.

Au, J, Youngentob, KN, Clark, RG, et al. 2017, <u>Bark chewing reveals a nutrient limitation of leaves</u> for a specialist folivore. Journal of Mammalogy 98(4), pp. 1185–1192.

Barth, BJ, FitzGibbon, SI, Gillett, A, et al. 2020, <u>Scattered paddock trees and roadside vegetation</u> <u>can provide important habitat for koalas (Phascolarctos cinereus) in an agricultural landscape</u>. Australian Mammalogy 42, pp. 194–203.

Battin, J 2004, When good animals love bad habitats: <u>Ecological traps and the conservation of</u> <u>animal populations</u>. Conservation Biology 18(6), pp. 1482–1491.

Baxter, PWJ and Hamilton, G 2018, <u>Learning to fly: Integrating spatial ecology with unmanned</u> <u>aerial vehicle surveys.</u> Ecosphere 9(4), p. e02194.

Beale, PK, Marsh, KJ, Foley, WJ et al. 2018, <u>A hot lunch for herbivores: physiological effects of elevated temperatures on mammalian feeding ecology</u>. Biological Reviews 93(1), pp. 674–692.

Beranek, CT, Roff, A, Denholm, B, et al. 2020, <u>Trialling a real-time drone detection and validation</u> protocol for the koala (Phascolarctos cinereus). Australian Mammalogy 43(2), pp. 260–264.

Beyer, HL, Villiers, D, Loader, J, et al. 2018, <u>Management of multiple threats achieves meaningful</u> <u>koala conservation outcomes.</u> The Journal of applied ecology 55(4), pp. 1966–1975.

Blyton, MDJ, Soo, RM, Whisson, D, et al. 2019, <u>Faecal inoculations alter the gastrointestinal</u> <u>microbiome and allow dietary expansion in a wild specialist herbivore, the koala</u>v. Animal Microbiome 1(1), p. 6.

Bowen, ME, McAlpine, CA, House, APN, et al. 2007, <u>Regrowth forests on abandoned agricultural</u> <u>land: A review of their habitat values for recovering forest fauna</u>. Biological Conservation 140(3), pp. 273–296.

Bowman, MJS, Williamson, GJ, Gibson, RK et al. 2021, <u>The severity and extent of the Australia</u> <u>2019–20 Eucalyptus forest fires are not the legacy of forest management</u>. Nature Ecology and Evolution 5, pp. 1003–1010.

Braithwaite, LW, Turner, J and Kelly, J 1984, <u>Studies on the arboreal marsupial fauna of eucalypt</u> forests being harvested for wood pulp at eden, NSW. iii. Relationships between faunal densities, <u>Eucalypt occurrence and foliage nutrients, and soil parent materials.</u>c Wildlife Research 11(1), pp. 41–48.

Brice, KL, Trivedi, P, Jeffries, TC, et al. 2019, <u>The Koala (Phascolarctos cinereus) faecal</u> microbiome differs with diet in a wild population. Peerj 7, p. e6534.

Briscoe, N, Handasyde, K, Griffiths, S, et al. 2014, <u>Tree-hugging koalas demonstrate a novel</u> thermoregulatory mechanism for arboreal mammals. Biology Letters 10, p. 20140235.

Briscoe, NJ, Kearney, MR, Taylor, CA, et al. 2016, <u>Unpacking the mechanisms captured by a</u> <u>correlative species distribution model to improve predictions of climate refugia</u>. Global Change Biology 22(7), pp. 2425–2439.

Burrows, GE 2002, <u>Epicormic strand structure in Angophora, Eucalyptus and Lophostemon</u> (<u>Myrtaceae</u>) – <u>implications for fire resistance and recovery</u>. New Phytologist 153(1), pp. 111– 131.

Callaghan, J, McAlpine, C, Thompson, J, et al. 2011, <u>Ranking and mapping koala habitat quality for</u> <u>conservation planning on the basis of indirect evidence of tree-species use: A case study of</u> <u>Noosa Shire, south-eastern Queensland</u>. Wildlife Research 38(2), pp. 89–102.

Ellis, W, Meltzer, A, Clifton, ID, Carrick, F, et al. 2010, <u>Climate change and the koala Phascolarctos</u> <u>cinereus: water and energy</u>. Australian Zoologist 35(2), pp. 369–377.

Chapin, FS 1980, <u>The Mineral Nutrition of Wild Plants</u>. Annual Review of Ecology and Systematics 11(1), pp. 233–260.

Clifton, ID 2010, <u>High koala mortality associated with low browse moisture in tropical</u> <u>environments</u>. Australian Mammalogy 32(2), pp. 157–159.

Clifton, ID, Ellis, WAH, Melzer, A, et al. 2007, <u>Water turnover and the northern range of the koala</u> (<u>Phascolarctos cinereus</u>). Australian Mammalogy 29(1), pp. 85–88.

Corcoran, E, Denman, S and Hamilton, G 2020, <u>New technologies in the mix: Assessing N-mixture</u> <u>models for abundance estimation using automated detection data from drone surveys</u>. Ecology and Evolution 10(15), pp. 8176–8185.

Corcoran, E, Denman, S and Hamilton, G 2021, <u>Evaluating new technology for biodiversity</u> <u>monitoring: Are drone surveys biased?</u> Ecology and Evolution 11(11), pp. 1–8.

Corcoran, E, Denman, S, Hanger, J, et al. 2019, <u>Automated detection of koalas using low-level</u> <u>aerial surveillance and machine learning</u>. Scientific Reports 9, p. 3208.

Cristescu, R, Ellis, W, de Villiers, D, et al. 2011, <u>North Stradbroke Island: An island ark for</u> <u>Queensland's koala population?</u> The Proceedings of the Royal Society of Queensland 117, pp. 309–334.

Cristescu, RH, Miller, RL, Schultz, AJ, et al. 2019a, <u>Developing noninvasive methodologies to</u> <u>assess koala population health through detecting Chlamydia from scats</u>. Molecular Ecology Resources 19(4), pp. 957–969.

Cristescu, RH, Banks, PB, Carrick, FN, et al. 2013, <u>Potential "ecological traps" of restored</u> <u>landscapes: Koalas Phascolarctos cinereus re-occupy a rehabilitated mine site</u>. PloS ONE 8(11), p. e80469.

Cristescu, RH, Foley, E, Markula, A, et al. 2015, <u>Accuracy and efficiency of detection dogs: A</u> <u>powerful new tool for koala conservation and management</u>. Scientific Reports 5(1), p. 8349.

Cristescu, RH, Goethals, K, Banks, PB, et al. 2012, <u>Experimental evaluation of koala scat</u> <u>persistence and detectability with implications for pellet-based fauna census</u>. International Journal of Zoology 2012, pp. 1–12.

Cristescu, RH, Miller, RL and Frere, CH 2020, <u>Sniffing out solutions to enhance conservation:</u> <u>How detection dogs can maximise research and management outcomes, through the example of</u> <u>koalas</u>. Australian Zoologist 40(3), pp. 416–432.

Cristescu, RH, Scales, KL, Schultz, AJ, et al. 2019b, <u>Environmental impact assessments can</u> <u>misrepresent species distributions: A case study of koalas in Queensland, Australia</u>. Animal Conservation 22(4), pp. 314–323.

Crowther, MS, Dargan, JR, Madani, G, et al. 2021, <u>Comparison of three methods of estimating the</u> <u>population size of an arboreal mammal in a fragmented rural landscape</u>. Wildlife Research 48(2), pp. 105–114.

Curtin, A, Lunney, D and Matthews, A 2002, A <u>survey of a low-density koala population in a</u> <u>major reserve system, near Sydney, New South Wales</u>. Australian Mammalogy 23(2), pp. 135– 144.

Davies, N, Gramotnev, G, Seabrook, L, et al. 2013, <u>Movement patterns of an arboreal marsupial at</u> the edge of its range: A case study of the koala. Movement Ecology 1(1), p. 8.

Davies, N, Gramotnev, G, Seabrook, L, et al. 2014, <u>Climate-driven changes in diet composition and</u> <u>physiological stress in an arboreal folivore at the semi-arid edge of its distribution</u>. Biological Conservation 172, pp. 80–88.

DAWE 2021a, The known and likely distribution of the koala dataset. Australian Government, Department of Agriculture, Water and the Environment. Canberra, ACT.

DAWE 2021b, <u>Consultation Document on Listing Eligibility and Conservation Actions for</u> <u>Phascolarctos cinereus (Koala)</u>. Department of Agriculture, Water and the Environment. Canberra, ACT.

DAWE 2022, <u>National Recovery plan for the Koala: Phascolarctos cinereus (combined</u> <u>populations of Queensland, New South Wales and the Australian Capital Territory</u>]. Department of Agriculture, Water and the Environment, Canberra. March 2022. CC BY 4.0.

DECC 2008, <u>Recovery plan for the Koala (Phascolarctos cinereus)</u>. NSW Department of Environment and Climate Change, NSW Government. Sydney, NSW.

DeGabriel, JL, Wallis, IR, Moore, BD, et al. 2008, A <u>simple, integrative assay to quantify nutritional</u> <u>quality of browses for herbivores.</u> Oceologia 156(1), pp. 107–116.

Dexter, CE, Appleby, RG, Edgar, JP, et al. 2016, <u>Using complementary remote detection methods</u> <u>for retrofitted eco-passages: A case study for monitoring individual koalas in south-east</u> <u>Queensland.</u> Wildlife Research 43(5), pp. 369–379.

Dique, DS, Penfold, G, Thompson, J, et al. 2001, <u>Koala distribution and density in southeast</u> <u>Queensland: The accuracy and precision of koala surveys</u>. In: Lyons, K., Melzer, A., Carrick, F., Lamb, D. ed. The Research and Management of Non-urban Koala Populations. Rockhampton, QLD: Koala Research Centre of Central Queensland, Central Queensland University, pp. 105–121.

Dique, DS, Preece, HJ, Thompson, J, et al. 2004, <u>Determining the distribution and abundance of a</u> <u>regional koala population in south-east Queensland for conservation management</u>. Wildlife Research 31(2), pp. 109–117.

Dique, DS, Thompson, J, Preece, HJ, et al. 2003a, <u>Dispersal patterns in a regional koala population</u> in south-east <u>Queensland</u>. Wildlife Research 30(3), pp. 281–290.

Dique, DS, Villiers, DL de and Preece, HJ 2003b, <u>Evaluation of line-transect sampling for</u> <u>estimating koala abundance in the Pine Rivers Shire, south-east Queensland</u>. Wildlife Research 30(2), pp. 127–133.

DoE 2014, <u>EPBC Act Referral Guidelines for the Vulnerable Koala (combined populations of</u> <u>Queensland, New South Wales and the Australian Capital Territory).</u> Department of the Environment, Australian Government. Canberra, ACT.

DPIE 2019, <u>Koala habitat information base technical guide</u>. Sydney: Department of Planning, Industry and Environment, NSW Government. Sydney, NSW.

DPIE 2020a, <u>Framework for the spatial prioritisation of koala conservation actions in NSW</u>. Department of Planning, Industry and Environment, NSW Government. Sydney, NSW.

DPIE 2020b, <u>NSW far south coast post-fire koala survey</u>. Parramatta: NSW Government, Department of Planning, Industry and the Environment. Sydney, NSW.

Ellis, W, Fitzgibbon, S, Melzer, A, et al. 2013, <u>Koala habitat use and population density: Using field</u> <u>data to test the assumptions of ecological models</u>. Australian Mammalogy 35(2), pp. 160–165.

Ellis, W, Bercovitch, F, Fitzgibbon, S, et al. 2011, <u>Koala bellows and their association with the</u> <u>spatial dynamics of free-ranging koalas</u>. Behavioral Ecology 22(2), pp. 372–377.

Ellis, WAH, Melzer, A, Carrick, FN, et al. 2002, <u>Tree use, diet and home range of the koala</u> (<u>Phascolarctos cinereus</u>) at <u>Blair Athol, central Queensland</u>. Wildlife Research 29(3), pp. 303– 311.

Ellis, WAH, Sullivan, BJ, Lisle, AT, et al. 1998, <u>The spatial and temporal distribution of koala</u> <u>faecal pellets</u>. Wildlife Research 25(6), pp. 663–668.

EPA 2016, <u>Koala habitat mapping pilot: NSW state forests</u>. Environment Protection Authority and State of NSW. Sydney, NSW.

Forman, RTT 1995, <u>Some general principles of landscape and regional ecology</u>. Landscape Ecology 10(3), pp. 133–142.

Gleadow, RM and Woodrow, IE 2002, <u>Defense chemistry of cyanogenic Eucalyptus cladocalyx</u> <u>seedlings is affected by water supply</u>. Tree Physiology 22(13), pp. 939–945.

Goldingay, RL and Dobner, B 2014, <u>Home range areas of koalas in an urban area of north-east</u> <u>New South Wales</u>. Australian Mammalogy 36(1), pp. 74–80.

Goldingay, RL and Taylor, BD 2017, <u>Targeted field testing of wildlife road-crossing structures:</u> <u>Koalas and canopy rope-bridges</u>. Australian Mammalogy 39(1), pp. 100–104.

Gras, EK, Read, J, Mach, CT, et al. 2005, <u>Herbivore damage, resource richness and putative</u> <u>defences in juvenile versus adult Eucalyptus leaves</u>. Australian Journal of Botany 53(1), pp. 33– 44.

Grimm-Seyfarth, A, Harms, W and Berger, A 2021, <u>Detection dogs in nature conservation: A</u> <u>database on their world-wide deployment with a review on breeds used and their performance</u> <u>compared to other methods</u>. Methods in Ecology and Evolution 12(4), pp. 568–579.

Hagens, SV, Rendall, AR and Whisson, DA 2018, <u>Passive acoustic surveys for predicting species'</u> <u>distributions: Optimising detection probability</u>. PLoS ONE 13(7), p. e0199396.

Hamilton, G, Corcoran, E, Denman, S, et al. 2020, <u>When you can't see the koalas for the trees:</u> <u>Using drones and machine learning in complex environments</u>. Biological Conservation 247, p. 108598.

Hasegawa, M 1995, <u>Habitat utilisation by koalas (Phascolarctos cinereus) at Point Halloran,</u> <u>Queensland.</u> Masters Thesis. Department of Zoology and Entomology. The University of Queensland, St Lucia, Queensland.

Jiang, A, Tribe, A and Murray, P 2019, <u>The development of an improved scat survey method for</u> <u>koalas (Phascolarctos cinereus)</u>. Australian Journal of Zoology 67(3), pp. 125–133.

Jurskis, V, Douch, A, McCray, K, et al. 2001, A <u>playback survey of the koala, Phascolarctos</u> <u>cinereus, and a review of its distribution in the Eden Region of south-eastern New South Wales</u>. Australian Forestry 64(4), pp. 226–231.

Kavanagh, RP, Stanton, MA and Brassil, TE 2007, <u>Koalas continue to occupy their previous home-ranges after selective logging in Callitris-Eucalyptus forest</u>. Wildlife Research 34(2), pp. 94–107.

Law, B, Caccamo, G, Roe, P, et al. 2017, <u>Development and field validation of a regional</u>, <u>management-scale habitat model: A koala Phascolarctos cinereus case study</u>. Ecology and Evolution 7(18), pp. 7475–7489.

Law, B, Gonsalves, L, Bilney, R, et al. 2020, <u>Using passive acoustic recording and automated call</u> <u>identification to survey koalas in the Southern forests of New South Wales</u>. Australian Zoologist 40(3), pp. 477–486.

Law, B, Gonsalves, L and Burgar, J 2021, Validation of spatial count models to estimate koala Phascolarctos cinereus density from acoustic arrays. NSW Department of Primary Industries. Unpublished work.

Law, BS, Brassil, T, Gonsalves, L, et al. 2018, <u>Passive acoustics and sound recognition provide</u> <u>new insights on status and resilience of an iconic endangered marsupial (koala Phascolarctos</u> <u>cinereus) to timber harvesting</u>. PLoS ONE 13(10), p. e0205075.

Leigh, C, Heron, G, Wilson, E, et al. 2019, <u>Using virtual reality and thermal imagery to improve</u> statistical modelling of vulnerable and protected species. PLoS ONE 14(12), p. e0217809.

Lollback, GW, Castley, JG, Mossaz, AC, et al. 2018, <u>Fine-scale changes in spatial habitat use by a</u> <u>low-density koala population in an isolated periurban forest remnant</u>. Australian Mammalogy 40(1), pp. 84–92.

Lunney, D, Gresser, S, O'Neill, L.E, et al. 2007, <u>The impact of fire and dogs on koalas at Port</u> <u>Stephens, New South Wales, using population viability analysis</u>. Pacific conservation biology 13(3), pp. 189–201.

Lunney, D, Matthews, A, Moon, C, et al. 2000, <u>Incorporating habitat mapping into practical koala</u> <u>conservation on private lands</u>. Conservation Biology 14(3), pp. 669–680.

Lunney, D, O'Neill, L, Matthews, A, et al. 2002, <u>Modelling mammalian extinction and forecasting</u> <u>recovery: Koalas at Iluka (NSW, Australia)</u>. Biological Conservation 106(1), pp. 101–113.

Lunney, D, Phillips, S, Callaghan, J, et al. 1998, <u>Determining the distribution of Koala habitat</u> across a shire as a basis for conservation: A case study from Port Stephens, New South Wales. Pacific Conservation Biology 4(3), pp. 186–196.

Lutze, M. and Faunt, K. 2006, <u>The East Gippsland Silvicultural Systems Project. III: Site</u> <u>occupancy, species composition and growth to 12 years</u>. Australian Forestry 69(3), pp. 198–212.

Marsh, KJ, Blyton, MDJ, Foley, WJ, et al. 2021, <u>Fundamental dietary specialisation explains</u> differential use of resources within a koala population. Oecologia 17, pp. 1–9.

Marsh, KJ, Blyton, MDJ, Foley, WJ, et al. 2014a, <u>Continuous monitoring of feeding by koalas</u> <u>highlights diurnal differences in tree preferences</u>. Wildlife Research 40(8), pp. 639–646.

Marsh, KJ, Blyton, MDJ, Foley, WJ, et al. 2014b, <u>Feeding rates of a mammalian browser confirm</u> the predictions of a "foodscape" model of its habitat. Oecologia 174(3), pp. 873–882.

Marsh, KJ, Saraf, I, Hocart, CH, et al. 2019, <u>Occurrence and distribution of unsubstituted B-ring</u> flavanones in Eucalyptus foliage. Phytochemistry 160, pp. 31–39.

Marsh, KJ, Wallis, IR. and Foley, WJ 2007, <u>Behavioural contributions to the regulated intake of plant secondary metabolites in koalas</u>. Oecologia 154(2), pp. 283–290.

Marsh, KJ, Ward, J, Wallis, IR, et al. 2018, <u>Intraspecific Variation in Nutritional Composition</u> <u>Affects the Leaf Age Preferences of a Mammalian Herbivore</u>. Journal of Chemical Ecology 44(1), pp. 62–71.

Masters, P, Duka, T, Berris, S, et al. 2004, <u>Koalas on Kangaroo Island: From introduction to pest</u> status in less than a century. Wildlife research (East Melbourne) 31(3), pp. 267–272.

Matthews, A, Lunney, D, Gresser, S, et al. 2007, <u>Tree use by koalas (Phascolarctos cinereus) after</u> fire in remnant coastal forest. Wildlife Research 34(2), pp. 84–93.

Matthews, A, Lunney, D, Gresser, S, et al. 2016, <u>Movement patterns of koalas (Phascolarctos cinereus) in remnant forest after fire.</u> Australian mammalogy 38(1), pp. 91–104.

McAlpine, C, Lunney, D, Melzer, A, et al. 2015, <u>Conserving koalas: A review of the contrasting</u> regional trends, outlooks and policy challenges. Biological Conservation 192, pp. 226–236.

McAlpine, CA, Rhodes, JR, Bowen, ME, et al. 2007, <u>Can multiscale models of species' distribution</u> <u>be generalized from region to region? A case study of the koala</u>. Journal of Applied Ecology 45(2), pp. 558–567.

McArthur, C, Marsh, NR, Close, DC, et al. 2003, <u>Nursery conditions affect seedling chemistry</u>, <u>morphology and herbivore preferences for Eucalyptus nitens</u>. Forest Ecology and Management 176(1), pp. 585–594.

McCallum, H, Kerlin, DH, Ellis, W, et al. 2017, <u>Assessing the significance of endemic disease in</u> <u>conservation—koalas, chlamydia, and koala retrovirus as a case study</u>. Conservation Letters 11(4), p. e12425.

McGregor, DC, Kerr, SE and Krockenberger, AK 2013, <u>The Distribution and Abundance of an</u> <u>Island Population of Koalas (Phascolarctos cinereus) in the Far North of Their Geographic</u> <u>Range</u>v. PLoS ONE 8(3), p. e59713.

Melzer, A 1995, <u>Aspects of the ecology of the koala, Phascolarctos cinereus (Goldfuss, 1817), in</u> <u>the sub-humid woodlands of central Queensland</u>. PhD thesis. The University of Queensland, St Lucia, Queensland.

Melzer, A, Carrick, F, Menkhorst, P, et al. 2000, <u>Overview, Critical Assessment, and Conservation</u> <u>Implications of Koala Distribution and Abundance</u>. Conservation biology 14(3), pp. 619–628.

Melzer, A. and Lamb, D 1994, Low density populations of the koala (Phascolarctos cinereus) in Central Queensland. Proceedings of the Royal Society of Queensland 104, pp. 89–93.

Mitchell, DL, Soto-Berelov, M, Langford, WT, et al. 2021, <u>Factors confounding koala habitat</u> <u>mapping at multiple decision-making scales</u>. Ecological Management & Restoration 22(2), pp. 171–182.

Mitchell, P 1990, Social behaviour and communication of koalas. In: Lee, A. K, Handasyde, K. A, Sanson, G.D, (World Koala Research Organisation PTY. LTD.) ed. Biology of the Koala. Chipping Norton, New South Wales: Surrey Beatty & Sons Pty Limited, pp. 151–170.

Moore, BD and Foley, WJ 2000, <u>A review of feeding and diet selection in koalas (Phascolarctos cinereus)</u>. Australian Journal of Zoology 48(3), pp. 317–333.

Moore, BD and Foley, WJ 2005, Tr<u>ee use by koalas in a chemically complex landscape</u>. Nature 435(7041), pp. 488–490.

Moore, BD, Foley, WJ, Wallis, IR, et al. 2005, <u>Eucalyptus foliar chemistry explains selective</u> <u>feeding by koalas</u>. Biology Letters 1(1), pp. 64–67.

Moore, BD, Lawler, IR, Wallis, IR, et al. 2010, <u>Palatability mapping: A koala's eye view of spatial</u> <u>variation in habitat quality</u>. Ecology 91(11), pp. 3165–3176.

Moore, BD, Wallis, IR, Marsh, KJ, et al. 2004a, <u>The role of nutrition in the conservation of the</u> <u>marsupial folivores of eucalypt forests</u>. In: Lunney, D. ed. Conservation of Australia's Forest Fauna. Mosman, N.S.W: Royal Zoological Society of New South Wales, pp. 549–575.

Moore, BD, Wallis, IR, Wood, JT, et al. 2004b, <u>Foliar nutrition, site quality, and temperature</u> <u>influence foliar chemistry of tallowwood (Eucalyptus microcorys)</u>. Ecological Monographs 74(4), pp. 553–568.

Mossaz, A 2010, <u>Estimating low-density Koala Populations in Southeast Queensland: Comparing</u> <u>the spot assessment technique and distance sampling</u>. PhD thesis. Griffith University, Gold Coast, Queensland.

Narayan, EJ and Williams, M 2016, <u>Understanding the dynamics of physiological impacts of</u> <u>environmental stressors on Australian marsupials, focus on the koala (Phascolarctos cinereus)</u>. BMC zoology 1(1), p. 1.

Nolan, RH, Gauthey, A, Losso, A, et al. 2021, <u>Hydraulic failure and tree size linked with canopy</u> <u>die-back in eucalypt forest during extreme drought</u>. New Phytologist 230(4), pp. 1354–1365.

OEH 2014, Koala Habitat Study Bellingen Shire Council Area. Report to Bellingen Shire Council. Office of Environment and Heritage, State of NSW Government. Sydney, NSW.

OEH 2018, <u>A review of koala tree use across New South Wales</u>. Office of Environment and Heritage, State of NSW Government. Sydney, NSW.

Osawa, R 1989, <u>Road-kills of the Swamp Wallaby, Wallabia bicolor, on North Stradbroke Island,</u> <u>Southeast Queensland.</u> Wildlife Research 16(1), pp. 95–104.

Padovan, A, Keszei, A, Foley, WJ, et al. 2013, <u>Differences in gene expression within a striking</u> <u>phenotypic mosaic Eucalyptus tree that varies in susceptibility to herbivory</u>. BMC plant biology 13(1), p. 29.

Pahl, LI and Hume, ID 1990, Preferences for *Eucalyptus* species of the New England Tablelands and initial development of an artificial diet for koalas. In: Lee, A. K, Handasyde, K. A, Sanson, G.D, (World Koala Research Organisation PTY. LTD.) ed. Biology of the Koala. Chipping Norton, New South Wales: Surrey Beatty & Sons Pty Limited, pp. 123–128.

Phillips, S, Brearley, G, Wallis, K, et al. 2019, <u>Redlands Coast Koala Population and Habitat</u> <u>Assessment Final Report to Redlands City Council April 2019</u>. Biolink Ecological Consultants.

Phillips, S and Callaghan, J 2000, <u>Tree species preferences of koalas (Phascolarctos cinereus) in</u> <u>the Campbelltown area south-west of Sydney, New South Wales</u>. Wildlife research (East Melbourne) 27(5), pp. 509–516.

Phillips, S and Callaghan, J 2011, <u>The Spot Assessment Technique: A tool for determining</u> <u>localised levels of habitat use by Koalas (Phascolarctos cinereus)</u>. Australian zoologist 35(3), pp. 774–779.

Phillips, S and Callaghan, J 2014, <u>What faecal pellet surveys can and can't reveal about the</u> <u>ecology of koalas Phascolarctos cinereus II: an interum response to Woosnam - Merchez et al</u>. (2013). Unpublished work.

Phillips, S, Callaghan, J and Thompson, V 2000, <u>The tree species preferences of koalas</u> (<u>Phascolarctos cinereus</u>) inhabiting forest and woodland communities on Quaternary deposits in the Port Stephens area, New South Wales. Wildlife research 27(1), pp. 1–10.

Phillips, S, Hopkins, M and JC 2007, <u>Koala habitat and population assessment for the city of the</u> <u>Gold Coast</u>. Biolink Ecological Consultants, Uki, NSW.

Phillips, S, Wallis, K. and Lane, A 2021, <u>Quantifying the impacts of bushfire on populations of wild koalas (Phascolarctos cinereus): Insights from the 2019/20 fire season</u>. Ecological Management & Restoration 22(1), pp. 80–88.

Polkinghorne, A, Hanger, J and Timms, P 2013, <u>Recent advances in understanding the biology</u>, <u>epidemiology and control of chlamydial infections in koalas</u>. Veterinary Microbiology 165(3–4), pp. 214–223.

Quigley, BL and Timms, P 2020, <u>Helping koalas battle disease - Recent advances in Chlamydia</u> <u>and koala retrovirus (KoRV) disease understanding and treatment in koalas</u>. FEMS Microbiology Reviews 44(5), pp. 583–605.

Ramsay, S 1999, <u>The ecology and dispersal patterns of juvenile koalas</u>, <u>Phascolarctos cinereus</u>, in <u>fragmented habitat</u>. PhD thesis. University of Sydney, Kensington, NSW.

Reindl-Thompson, SA, Shivik, JA, Whitlaw, A, et al. 2006, <u>Efficacy of scent dogs in detecting black-footed ferrets at a reintroduction site in south dakota</u>. Wildlife Society Bulletin 34(5), pp. 1435–1439.

Rhodes, JR, Callaghan, JG, McAlpine, CA, et al. 2008, <u>Regional variation in habitat-occupancy</u> <u>thresholds: A warning for conservation planning</u>. Journal of Applied Ecology 45(2), pp. 549–557.

Rhodes, JR, Lunney, D, Moon, C, et al. 2011, <u>The consequences of using indirect signs that decay</u> to determine species' occupancy. Ecography 34(1), pp. 141–150.

Robbins, A, Loader, J, de Villiers, D, et al. 2019, <u>Predation by carpet pythons (Morelia spilota) is</u> an important cause of mortality in a free-living koala (Phascolarctos cinereus) population in <u>South East Queensland</u>. Australian veterinary journal 97(9), pp. 351–356.

Schultz, AJ, Cristescu, RH, Littleford-Colquhoun, BL, et al. 2018, <u>Fresh is best: Accurate SNP genotyping from koala scats</u>. Ecology and Evolution 8(6), pp. 3139–3151.

Seabrook, L, McAlpine, C, Baxter, G, et al. 2011, <u>Drought-driven change in wildlife distribution</u> <u>and numbers: A case study of koalas in south west Queensland</u>. Wildlife Research 38(6), pp. 509–524.

Seabrook, L, McAlpine, C, Rhodes, J, et al. 2014, <u>Determining range edges: Habitat quality, climate</u> or climate extremes? Diversity & distributions 20(1), pp. 95–106.

SEPP 2021, <u>State Environmental Planning Policy (koala habitat protection) 2021</u>. NSW Department of Planning Industry and Environment, NSW Government. Sydney, NSW.

Sluiter, AF, Close, RL and Ward, SJ 2002, <u>Koala feeding and roosting trees in the Campbelltown</u> area of New South Wales. Australian Mammalogy 23(2), pp. 173–175.

Smith, AG, McAlpine, C, Rhodes, J, et al. 2013, <u>Are there habitat thresholds in koala occupancy in</u> <u>the semiarid landscapes of the Mulgalands Bioregion</u>? Wildlife research (East Melbourne) 40(5), pp. 413–426.

Smith, AP 2004, <u>Koala conservation and habitat requirements in a timber production forest in</u> <u>north-east New South Wales</u>. In: Lunney, D. ed. Conservation of Australia's Forest Fauna. Mosman, N.S.W: Royal Zoological Society of New South Wales, pp. 591–611.

Stanton, JP and Morgan, MG 1977, <u>The rapid selection and appraisal of key and endangered sites:</u> <u>The Queensland case study.</u> Canberra: Australia Department of Environment, Housing and Community Development.

Sullivan, BJ, Baxter, GS. and Lisle, AT 2002, <u>Low-density koala (Phascolarctos cinereus)</u> populations in the mulgalands of south-west Queensland. I. Faecal pellet sampling protocol. Wildlife Research 29(5), pp. 455–462.

Sullivan, BJ, Baxter, GS, Lisle, AT, et al. 2004, <u>Low-density koala (Phascolarctos cinereus)</u> <u>populations in the mulgalands of south-west Queensland</u>. IV. Abundance and conservation status. Wildlife Research 31(1), pp. 19–29.

Thackway, R and Cresswell, ID 1995, <u>An Interum Biogeographic Regionalisation for Australia: A</u> <u>framework for establishing the national system of reserves</u>. 4th ed. Australian Nature Conservation Agency, Reserve Systems Unit.

Timms, P 2005, <u>Chlamydial infection and disease in the koala</u>. Microbiology Australia 26(2), pp. 65–68.

Tun, UN, 1993, <u>Re-establishment of rehabilitated koalas in the wild and their use of habitat in</u> <u>Sheldon, Redland shire, South East Queensland, with particular reference to dietary selection</u>. M Sc thesis. School of Biological Sciences. The University of Queensland, Brisbane, Queensland. Wedrowicz, F, Karsa, M, Mosse, J, et al. 2013, <u>Reliable genotyping of the koala (Phascolarctos cinereus) using DNA isolated from a single faecal pellet</u>. Molecular Ecology Resources 13(4), pp. 634–641.

Wedrowicz, F, Mosse, J and Hogan, F 2018, <u>Genetic structure and diversity of the koala</u> <u>population in South Gippsland, Victoria: A remnant population of high conservation significance</u>. Conservation Genetics 19, pp. 713–728.

Wedrowicz, F, Mosse, J, Wright, W, et al. 2017a, <u>Validating the use of non-invasively sourced</u> <u>DNA for population genetic studies using pedigree data</u>. Web Ecology 17(1), pp. 9–18.

Wedrowicz, F, Wright, W, Schlagloth, R, et al. 2017b, <u>Landscape, koalas and people: A historical</u> <u>account of koala populations and their environment in South Gippsland</u>. Australian zoologist 38(4), pp. 518–536.

Whisson, DA, Dixon, V, Taylor, ML, et al. 2016, <u>Failure to respond to food resource decline has</u> catastrophic consequences for koalas in a high-density population in southern Australia. PLoS ONE 11(1), p. e0144348.

White, NA 1999 <u>Ecology of the koala (Phascolarctos cinereus) in rural south-east Queensland,</u> <u>Australia</u>. Wildlife Research 26(6), pp. 731–744.

White, NA and Kunst, ND 1990, Aspects of the ecology of the koala in south-eastern Queensland. In: Lee, A. K, Handasyde, K. A, Sanson, G.D, (World Koala Research Organisation PTY. LTD.) ed. Biology of the Koala. Chipping Norton, New South Wales: Surrey Beatty & Sons Pty Limited, pp. 109–116.

Wiegand, T, Revilla, E and Moloney, KA 2005, <u>Effects of Habitat Loss and Fragmentation on</u> <u>Population Dynamics.</u> Conservation Biology 19(1), pp. 108–121.

Wilmott, L, Cullen, D, Madani, G, et al. 2019, <u>Are koalas detected more effectively by systematic</u> <u>spotlighting or diurnal searches?</u> Australian Mammalogy 41(1), pp. 157–160.

Witt, RR, Beranek, CT, Howell, LG, et al. 2020, <u>Real-time drone derived thermal imagery</u> <u>outperforms traditional survey methods for an arboreal forest mammal</u>. PLoS ONE 15(11), p. e0242204.

Woodward, W, Ellis, WA, Carrick, FN, et al. 2008, <u>Koalas on North Stradbroke Island: Diet, tree</u> <u>use and reconstructed landscapes.</u> Wildlife Research 35(7), pp. 606–611.

Woosnam-Merchez, O, Cristescu, R, Dique, D, et al. 2012, <u>What faecal pellet surveys can and can't</u> <u>reveal about the ecology of koalas Phascolarctos cinereus</u>. Australian Zoologist 36(2), pp. 192–200.

Youngentob, KN, Lindenmayer, DB, Marsh, KJ, et al. 2021, <u>Food intake: an overlooked driver of climate change casualties?</u> Trends in ecology & evolution (Amsterdam).