Review of the Coastal Integrated Forestry Operations Approvals koala browse tree list for the Upper and Lower North East subregion

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Executive Summary

In order to protect koalas and their habitat during forest harvesting, the Coastal Integrated Forestry Operations Approvals (IFOA) identifies a set of koala browse tree species that must be retained at a specific level during forest harvesting. For the Upper and Lower North East Subregions, the Coastal IFOA lists three primary koala browse trees, which must constitute at least 50% of retained browse trees where available, and further secondary browse trees.

Recent research independently commissioned and overseen by the NSW Natural Resources Commission (NRC) under its Koala Research Program indicated that browse tree classifications may not adequately reflect the diets and value of tree species for koalas in forests managed under the Coastal IFOA. Scats collected from koalas within the study area contained high proportions of DNA from some tree species that are not listed in the Coastal IFOA or are listed as secondary browse trees. These were ironbarks (particularly *Eucalyptus paniculata* and *E. siderophloia*), spotted gum (*Corymbia maculata*) and small-fruited grey gum (*E. propinqua*). Another unlisted species, flooded gum (*E. grandis*) was also flagged because of its high potential nutritional quality for koalas, similar to known browse species. Based on these findings, this review was funded under the Coastal IFOA monitoring program.

This review identifies and evaluates the extent of scientific evidence (published and unpublished) supporting the listing of ironbarks (particularly *E. paniculata* and possibly *E. siderophloia*), flooded gum (*E. grandis*) and spotted gum (*C. maculata*) as secondary browse species, and the elevation of small-fruited grey gum (*E. propinqua*) from a secondary to primary browse species. It also considers the evidence to support the positions of other eucalypt species currently listed in the Coastal IFOA koala browse tree list, and whether there may be scope to remove or substitute some species to enhance Coastal IFOA outcomes.

We gathered information about koala browse tree use from three types of sources:

1. We considered a newly revised and expanded analysis of koala diet composition based upon the molecular faecal diet composition analysis (MFDCA) that in part, prompted this review. This revised analysis increased the number of scat samples considered from 45 to 191 and increased the number of marker reads from each sample, allowing a more confident assessment of proportional marker composition in each scat. The larger dataset also allowed us to make a preliminary assessment of the magnitude of bias in the original results, whereby the DNA from less digestible leaves survives passage of the gut to a greater extent than that of more digestible ones, inflating the importance of those less digestible species. After applying a crude correction for these biases where possible, we concluded that the original study had underestimated the contribution of tallowwood (*E. microcorys*) to koala diets and overestimated the importance of spotted gum (*C. maculata*) and probably the ironbarks.
2. We collated information from the literature about koala use of eucalypt species on the current coastal IFOA browse tree list and summarised this in a table.

Overall, the information suggested that the grey gums (*E. propinqua* and *E. punctata*) are used extensively by koalas, and that spotted gum (*C. maculata*) and the ironbarks are used sometimes but are not generally preferred. Evidence for the used of flooded gum (*E. grandis*) was mixed, possibly reflecting regional variation. This exercise also revealed scant support for the retention of some secondary food trees currently on the browse tree list.

3. We interviewed ten experts with knowledge of koala browse tree preferences in the upper and lower northeast subregions. Interviews were structured to elicit information about unpublished or privately held sources of data about patterns of koala feeding and tree use as well as perceived importance of species on the current tree list, reactions to proposed alterations and perceived risks associated with change. These expert opinions are collated and summarised.

After considering these three sources of data, we suggest that tallowwood (*E. microcorys*), swamp mahogany (*E. robusta*), forest red gum (*E. tereticornis*) and slaty red gum (*E. glaucina*) be retained as primary browse trees. We also suggest that **narrow-leaved red gum (**E¡.seeana**) and its hybrids be demoted from the primary browse list to the secondary list**. All three sources of information supported the significant use of the grey gums (*E. punctata, E. propinqua* and *E. canaliculata*) as browse by koalas. Rather than elevate these species to the primary list however, which might have the detrimental effect of reducing the retention of tallowwood (*E. microcorys*) under some circumstances, we suggest that the **grey gums be classified to a new separate tier between primary and secondary ('primary level 2')**. This would allow retention of primary browse trees to be prioritized, while also ensuring that the grey gums are recognised as more valuable than secondary browse trees.

Due to a lack of support for their use by koalas in this region, we also **suggest the removal of** E. radiata **(narrow-leaved peppermint),** E¡.nobilis.**(ribbon gum),** E. obliqua **(messmate),** E¡.pauciflora.**(snow gum),** E¡.andrewsii.**(New England blackbutt) and** E¡.campanulata.**(New England blackbutt) from the secondary browse list**. **We suggest that the ironbarks (**E. siderophloia.**and** E. paniculata**), spotted gum (*C. maculata*) and flooded gum (**E¡.grandis**) not be added to the secondary browse tree list, but that red mahogany (**E. resinifera**) should be.**

Finally, this review considers environmental risks associated with changes to the koala browse tree list and identifies knowledge gaps. Addressing these knowledge gaps would increase confidence around the suitability of the current Coastal IFOA protocols.

Introduction

Koala browse trees for the Upper North East and Lower North East Subregions under current Coastal Integrated Forestry Operations Approvals

The Coastal Integrated Forestry Operations Approvals (IFOA) provide the framework for regulating native timber harvesting in NSW coastal state forests. The purpose of the Coastal IFOA is to facilitate ecologically sustainable forest management by imposing harvesting conditions that protect species and their habitats in coastal forest ecosystems. This includes the identification of koala browse trees that must be retained during forest harvesting.

For the Upper and Lower North East Subregions, the Coastal IFOA lists three primary koala browse trees, which must constitute at least 50% of retained browse trees where available:

- Tallowwood (*Eucalyptus microcorys*)
- Swamp mahogany (*E. robusta*)
- Red gums (*E. tereticornis, E. glaucina, E. seeana* and hybrids)

The remainder of the trees may be from the secondary browse list:

- Grey gums (*E. biturbinata*[1], *E. propinqua, E. punctata, E. canaliculata*)
- Grey box (*E. moluccana, E. largeana*)
- Peppermints (*E. radiata, E. acaciiformis*)
- Sydney blue gum (*E. saligna*)
- Ribbon gum (*E. nobilis, E. viminalis*)
- Messmate (*E. obliqua*)
- Snow gum (*E. pauciflora*)
- Mountain gum (*E. dalrympleana*)
- New England blackbutt (*E. andrewsii, E. campanulata*).

Reviewing the koala browse tree list

Recent research independently commissioned and overseen by the NSW Natural Resources Commission (NRC) under its Koala Research Program[2] indicated that browse tree classifications may not adequately reflect the diets and value of tree species for koalas in forests managed under the Coastal IFOA. Scats collected from koalas within the study area contained high proportions of some tree species that are not listed in the Coastal IFOA or are listed as secondary browse trees. These were:

- Ironbarks (particularly *E. paniculata* and *E. siderophloia*)
- Spotted gum (*Corymbia*[3] *maculata*)

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[1] *E. biturbinata* is commonly placed in synonymy with *E. punctata* (Slee et al. 2020, Nicolle 2024)

[2] Program funded under the NSW Koala Strategy

[3] Crisp et al. (2024) have proposed a taxonomic name change from *C. maculata* to *Blakella maculata*. The debate over the major revisions to eucalypt taxonomy proposed by that paper can be expected to continue for some time. In response Nicolle (2024) has proposed that all three eucalypt genera, *Eucalyptus*, *Angophora* and *Corymbia* be collapsed back into a single genus, *Eucalyptus*. We have not incorporated either of these new taxonomic schemes into this report.

- Small-fruited grey gum (*E. propinqua*)

Another unlisted species was also flagged because of its high potential nutritional quality for koalas, similar to known browse species. This was:

- Flooded gum (*E. grandis*)

Based on these findings, the NRC recommended the NSW Forest Monitoring Steering Committee (the Steering Committee) review the Coastal IFOA koala browse tree list to ensure that the highest value browse species are retained during forestry operations. The Committee accepted the recommendation, and funded the review under the Coastal IFOA monitoring program.

Scope of work

This document aims to deliver high quality expert advice to assist the NSW NRC and Steering Committee in considering advising the NSW Government and relevant agencies on the addition of new species to the Coastal IFOA koala browse tree list, along with any potential environmental risks linked to such additions.

The review specifically identifies and evaluates the extent of scientific evidence (published and unpublished) supporting the following changes to the Coastal IFOA koala browse tree list:

1. List ironbarks (particularly *E. paniculata* and possibly *E. siderophloia*), flooded gum (*E. grandis*) and spotted gum (*C. maculata*) as secondary browse species.
2. Elevate small-fruited grey gum (*E. propinqua*) from a secondary to primary browse species.

For comparison, the review also considers the evidence to support the eucalypt species currently listed in the Coastal IFOA koala browse tree list, or whether there may be scope to remove or substitute some species to enhance Coastal IFOA outcomes.

Approach

We sourced information about koala browse tree use from three types of sources.

1. We considered a revised and expanded analysis of koala diet composition based upon molecular faecal diet composition analysis (MFDCA). This analysis is based on the same study previously reported by Moore et al (2022), the results of which partially prompted this revision.
2. We collated information from the literature (peer-reviewed journal articles, scientific reports, and theses) about koala use of eucalypt species on the current coastal IFOA browse tree list. This information is drawn from throughout Australia in some cases and so may not always directly inform the significance of species for the region in question.
3. We interviewed ten experts with knowledge of koala browse tree preferences. An initial list of names was provided by the NRC, and this was altered and expanded in response to suggestions from the interviewees themselves. Most interviews were conducted in December 2023 and lasted from 1 – 1.5 hours. We also separately reviewed two major studies on koala browse trees (McAlpine et al 2023, Radford Miller 2012) that were consistently referred to by multiple interviewees. Interviews were structured to elicit information about unpublished

or privately held sources of data about patterns of koala feeding and tree use as well as perceived importance of species on the current tree list, reactions to proposed alterations and perceived risks associated with change.

Types of evidence for the importance of koala browse trees

Koala browse tree preferences are inferred from multiple different types of data, which differ in the strength of evidence they provide. This is well understood and has been discussed at length elsewhere (e.g. Moore and Foley 2000). Briefly however, much of our understanding is based on observations of tree use by koalas, either from observations of koalas (opportunistic, during surveys, or during radiotracking) or of koala scat. These data may not always reflect the use of trees for feeding (i.e. it may not indicate that these are browse trees), because tree use, particularly during the day, is influenced by factors such as shelter characteristics and the location of other koalas (e.g. Law et al. 2023).

Evidence of actual browsing by koalas is rarer but can sometimes be obtained from radiotracking studies and can be inferred from analysis of plant remains (cuticle or DNA) in koala faecal pellets. The faecal approach offers solid evidence that certain trees have been consumed and how frequently, but is subject to biases discussed below. The quality of trees as browse can also be understood in relation to analysis of foliage for nutrient and toxin concentrations, although koala preferences do not always correspond perfectly to expectations. Finally, browse trees can be identified on the basis of feeding to captive koalas, in an experimental setting or in the care of hospitals or zoos. However, such trials reflect an unnatural situation where koalas, which may be unwell or have received additional nutritional supplements, are not necessarily free to make the diet choices they would make in the wild. Furthermore, actual amounts consumed are not often recorded, but rather conclusions are drawn from what is offered, or an approximation of relative consumption rates and koala relative preferences.

Koala use of browse trees is inevitably context-dependent. Researchers often assess koala tree preference by comparing rates of use to the availability of trees, but this can under- or over-estimate the nutritional significance of trees for rare or very locally abundant species. The nutritional quality and hence preference for trees can also differ across soil types and physical environments (e.g. differing rainfall, temperature, elevation). Rates of use of tree species are also influenced by the proximity and abundance of alternative browse trees in the locality. Despite these complicating factors, koalas are exceptionally well-studied, and there is sufficient data of many types, from many sources, to allow us to draw some conclusions.

Results

1. Revised and expanded evidence from faecal diet composition analysis.

Uncertainty around the significance of some koala food tree species was in part a product of findings from a report to the Natural Resources Commission (Moore et al. 2022), which deployed a new method of molecular faecal diet composition analysis (MFDCA), based upon the detection of eucalypt DNA in koala scat (faecal pellets), to characterise what koalas had been eating (Blyton et al. Preprint (2023)). When it is successful, this approach quantitatively detects copies of multiple markers particular to the food trees recently consumed by the koala. The report suggested a more significant role for the ironbarks (*E. paniculata* and possibly *E. siderophloia*) and spotted gum (*C. maculata*) than had previously been understood, and also raised the question of whether small-fruited grey gum (*E. propinqua*) should be elevated from a secondary to primary browse tree.

Data returned from MFDCA can be interpreted to provide two different measures of diet composition. The first of these is the proportion of scats in which each food tree species is detected, and the second is the proportion of all markers in the scat attributable to each food tree species. The second measure can be considered for each scat sample, for all scat samples from an individual koalas or koala population, or for all scat samples considered together.

Original findings and limitations

The study reported by Moore et al. (2022) found that koalas on the North Coast of NSW consumed a diverse mixture of tree species, with 50% of the population's diet estimated to comprise *E. propinqua* (small-fruited grey gum), ironbarks (the method is unable to distinguish *E. siderophloia* from *E. paniculata*) and *E. microcorys* (tallowwood). A further 30% was comprised of *C. maculata* (spotted gum), *E. pilularis* (blackbutt) and two bloodwood species (*C. gummifera* and *C. intermedia*; also indistinguishable). *E. microcorys* (tallowwood) was the most commonly detected species, found in 62% of scats, and all species or species pairs named above were also detected at rates of 40% or greater. Markers for *E. microcorys* (tallowwood) accounted for a relatively small mean proportion (23%) of markers in scats in which they were detected, compared to its frequency of use, whereas less frequently used species such as ironbarks (93%) and *E. pilularis* (blackbutt) (65%) made up much larger proportions of the scats in which they were found.

A caveat emphasised by Moore et al (2022) was that any approach that relies on the analysis of faecal samples for the determination of diet composition should be considered semi-quantitative in nature. This is because numerous factors affect the rates of detection of markers relative to the consumption of each species. First, it is possible that DNA concentration per gram of leaf consumed differs among different food trees or types of foliage. This could occur if mean cell size differs amongst trees, for example if some species have thicker cell walls, or because the cells of young leaf tips, which are still expanding into mature leaves, are smaller. Second, we can anticipate that more DNA will survive passage of the koala gut when it belongs to poorly digestible tree species, because it is protected from digestion by thick, more highly lignified plant cell walls which protect cell contents, including the nucleus. Digestion may be further reduced by some plant secondary metabolites, such as tannins. These two processes might counter each other to some extent (more digestible plants may contain relatively more DNA to start with, but less of it might survive to the faeces), but based upon what we know from other studies using faecal markers of digestion, the second process is likely to be more significant, and the contribution of more digestible species to the diet is likely to be underestimated relative to that of poorly digestible species (Garnick et al. 2018). In general, those more digestible species are also the species likely to be preferred by herbivores.

Despite the collection of 260 koala scat samples for the study of Moore et al (2022), poor DNA quality meant that sequencing only returned useful data from 45 samples. Furthermore, the numbers of DNA markers detected even in those samples was small, meaning that rare markers from species that were more comprehensively digested or which were consumed in small amounts, may have been missed. The 45 samples that 'worked' were mostly from a single koala population and were skewed towards collections from a few radiotracked individuals. This raised questions about the representativeness of estimated diet composition, and whether the findings can reasonably be assumed to describe the North Coast koala population more broadly.

Revisiting the diet composition analysis

Since completing the project discussed above, Ben Moore and Michaela Blyton have continued to apply the MFDCA to koala populations in other parts of Australia, including a broad survey of Queensland which analysed 455 koala scat samples with a success rate of 75%. This was despite many of the Queensland scat samples being much older and in poorer condition than those used for North Coast NSW. Upon reviewing the analysis steps in Moore et al. (2022), we eventually identified that the external sequencing company used to perform the laboratory analysis of DNA in koala scat had neglected to perform a requested DNA cleanup step prior to sequencing. Fortunately, the company still had DNA from our work and was able to clean this up and re-sequence it. As a result, we now have an expanded analysis of the samples described in Moore et al. (2022). We are in the process of preparing a revised report and publishing our findings, but they are summarised below.

We now have useful diet composition data from 191 scat samples (rather than 45) and a much larger number of reads (allowing a more confident assessment of proportional marker composition in each scat) from each. The mean number of food tree species detected in scats was four. *Eucalyptus microcorys* (tallowwood) was easily the most frequently detected species, detected in 83% of scat samples (Fig. 1). This suggests that no more than 1 in 6 koalas across the study region had failed to feed from this species at some time in the 2 or 3 days preceding. It is also consistent with koalas having fed from this species on approximately every second day average (see explanation below, and figure 2). *Eucalyptus propinqua* (small-fruited grey gum) was the second most frequently consumed species (61%). In both cases, the larger dataset revealed more frequent detection of these species than previously (previously 62% for *E. microcorys* (tallowwood) and 40% for *E. propinqua* (small-fruited grey gum)). *Corymbia maculata* (spotted gum) was detected less frequently than our original analysis had suggested (38% c.f. 47%), as was *E. pilularis* (blackbutt) (39% c.f. 44%). The frequency of detection of ironbarks was the same in both analyses (23%). The clear picture that emerges is that in these forests *E. microcorys* (tallowwood) and *E. propinqua* (small-fruited grey gum) are the key food tree species. Only 8% of scat samples did not contain DNA from one or both of these species.

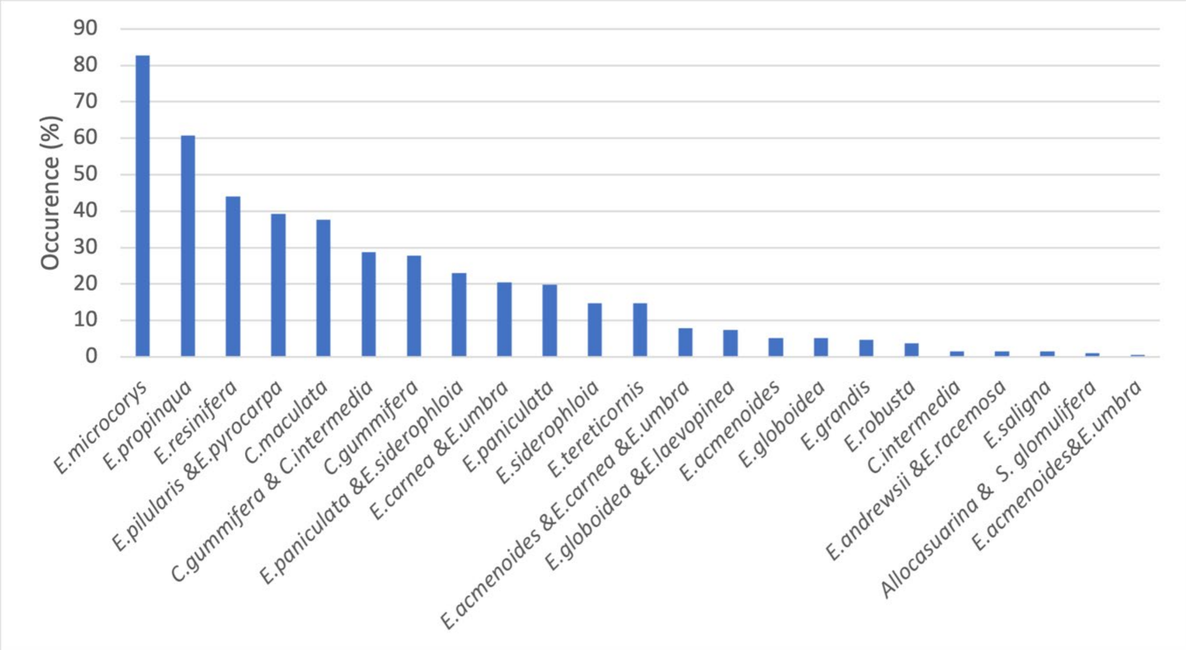

Figure 1. The frequency of occurrence (detection) of food tree species in 191 koala scat samples.

It should be noted that the frequency of detection of a browse species in scat does not correspond directly to the frequency of consumption. This is because markers from a meal persist in the scat for some days after consumption of a meal, meaning that markers in scat will be detected on more days than a species is eaten. For traditional leaf cuticle markers, markers can easily be detected three days after consumption for several species, and sometimes up until six days (Ellis et al. 1999). At present, we are lacking equivalent data for DNA markers, but we can expect that more digestible species such as tallowwood might be detectable for a shorter duration after consumption than less digestible species (e.g. ironbarks). Figure 2 illustrates the results of a simulation comparing the frequency of consumption (what percentage of days a species is eaten) with the frequency of detection in faeces (what proportion of scats a species is detected in). These simulations distributed feeding randomly in time, and are shown for three different levels of persistence of markers in scat: 2 days, 3 days and 4 days.

Semiquantitative estimates of relative diet composition based upon DNA marker abundance did not differ so greatly between the original and revised analyses. For example, the overall relative abundance of markers from *E. microcorys* (tallowwood) and *E. propinqua* (small-fruited grey gum) were 14% and 19% in the original analysis and 13% and 18% in the revised analysis. However, the larger quantity of data allowed us to make a crude estimate of the relative persistence of markers from each species as consumed leaf passes through the koala's digestive system.

One approach to estimating the relative persistence of DNA markers for each species is to identify scat samples which contain only markers from a single species. In these samples, the total number of marker reads should indicate the strength with which that species' markers are represented in scat. Unfortunately, very few scat samples contained a single eucalypt species, and this was particularly the case for *E. microcorys* (tallowwood). An alternative approach is to fit a linear regression model describing the number of marker reads attributable to a species as a function of the proportion of all markers in the scat sample belonging to that species. The slope of this regression model can also act as an index of relative marker persistence. This approach is imperfect for a number of reasons. First, the mathematical forms of the true relationships are not linear and second, the number of markers from a species, expressed as a proportion of total markers in the sample, is not properly representative of the proportional consumption of each species. Nonetheless, our simulations show that, given adequate representation of a species in scats, the slope of this linear regression provides an acceptable relative measure of DNA persistence in the scat. We are currently planning future controlled feeding trials with captive koalas to rigorously quantify differential plant DNA persistence with respect to other readily measurable traits associated with leaf digestibility (e.g. *in vitro* digestibility; cell wall composition).

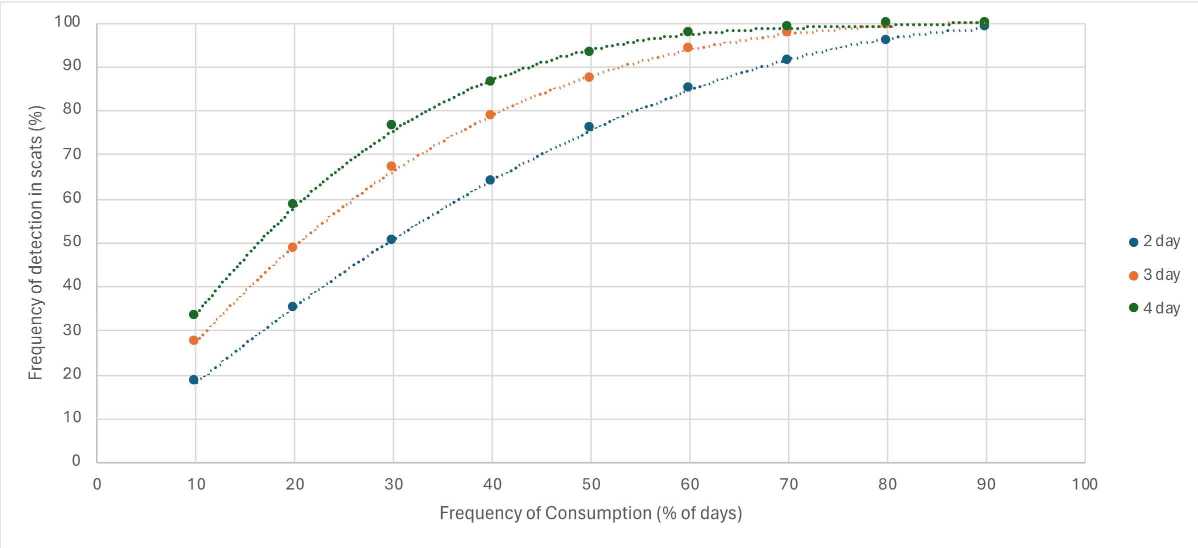

Figure 2: Simulated frequency of detection of markers in scat as a function of frequency of consumption (as a percentage of days a species was consumed), for three levels of marker persistence post-consumption.

We used the regression approach described above with eucalypt species that were detected in enough scats and that exhibited a sufficiently broad range of proportional representation in scats to allow us to estimate the slope of a linear regression. We fitted models for *E. microcorys* (tallowwood), *E. propinqua* (small-fruited grey gum), *E. resinifera* (red mahogany), *E. pilularis* (blackbutt) and *C. maculata* (spotted gum). *Eucalyptus microcorys* (tallowwood) unambiguously produced the shallowest regression slope – this is, its DNA was least persistent in faeces, suggesting the leaf of this species is highly digestible. This is unsurprising and consistent with the high rates of use of this tree by koalas. The slopes for *E. microcorys* (tallowwood), *E. propinqua* (small-fruited grey gum), *E. resinifera* (red mahogany), *E. pilularis* (blackbutt) and *C. maculata* (spotted gum) were 2.0, 5.0, 4.2, 2.8, 6.7. Because *E. microcorys* (tallowwood) was the most frequently used tree and showed the lowest DNA persistence, we can express the persistence of other species relative to it as: *E. propinqua* = 2.5; *E. resinifera* = 2.1; *E. pilularis* = 1.4 and *C. maculata* = 3.4.

These correction factors are only crude approximations, but they suggest that the proportional abundance of marker reads in scats underestimates the consumption of *E. microcorys* (tallowwood) relative to all other species. For example, where proportional marker read counts suggest that *E. microcorys* (tallowwood) and *E. propinqua* (small-fruited grey gum) were consumed in equal amounts, the reality may be that they were consumed in a ratio of 2:1. Consumption of species with steeper slopes, like *C. maculata* (spotted gum), is overestimated relative to most other species. It is difficult to estimate an appropriate correction factor for the ironbarks, because they were consumed less frequently, and because the estimates of their consumption rely on three separate groups of markers. However, it seems likely that one or both of the ironbarks under consideration (*E. siderophloia* and *E. paniculata*) have especially persistent DNA.

Understanding the ranking of species in terms of DNA persistence, but not the actual duration of persistence, does not help us to quantitatively convert estimates of frequency of detection of food trees in scat to frequency of consumption. It is certain though that more indigestible species might be detected more frequently at very low concentrations than their true dietary importance warrants. This might particularly be the case for the ironbarks and it is likely that the original report almost certainly strongly overestimated the significance of ironbarks in koalas' diets. The relative differences in DNA persistence can however be used to correct our estimates of the proportional composition of koala diets. If we apply these correction factors, remaining aware of their limitations, and ignoring the contribution of minor dietary components, we find that *E. microcorys* (tallowwood) might account for 30% of koala diets, *E. propinqua* (small-fruited grey gum) for 17%, *E. resinifera* (red mahogany) for 8%, *E. pilularis* (blackbutt) for 11% and *C. maculata* (spotted gum) for 8%, rather than the 13%, 18%, 8%, 7% and 12% estimated initially.

While we emphasise again that these correction factors are crude estimates, applying them likely gives a truer picture of koala diet composition than not. We undertook a similar exercise with data collected from our Queensland study, which included many species in common with our North Coast study. Using the regression approach, it again emerged that DNA from *E. microcorys* (tallowwood) showed low persistence, although the red gums *E. tereticornis*, *E. camaldulensis* and *E. amplifolia* were similar or slightly lower, along with *E. robusta* (swamp mahogany). *Eucalyptus propinqua* (small-fruited grey gum) was considerably higher than *E. microcorys* (tallowwood) and the least digestible Queensland species for which we could assess persistence was *E. exserta* (Queensland peppermint). In the Queensland dataset, we had more instances where scats contained a single species only, allowing us to use the alternative approach for estimating relative DNA persistence. This produced the persistence ranking *E. microcorys* < *E. camaldulensis* < *E. amplifolia* < *E. tereticornis* << *E. propinqua* << *E. populnea* << *E. exserta*.

2. Review of literature

We reviewed existing literature about koala use of trees on the Costal IFOA secondary browse tree list and the proposed additional species. This information is summarised in table 1. For each species, the literature is grouped according to whether it provides diet-based information (e.g. feeding observations or faecal analysis; coloured purple), observations of tree use (yellow), or it reviews other sources of information (green).

There was strong evidence from many studies that grey gums (***E. punctata*** and ***E. propinqua)*** are used extensively by koalas and can be a large component of the diet in some areas. Both species are regularly fed to koalas in captivity, and, in some cases, koalas have been maintained exclusively on these species for extended periods of time.

There is limited published evidence for or against the use of grey boxes (E¡.moluccana and E¡.largeana) by koalas.

Several studies suggest that koalas may occasionally eat ***E. radiata*** (narrow-leaved peppermint) in Victoria, but it is more often avoided. Little is known about the other listed peppermint species, ***E. acaciiformis***, but one study suggested that it may be a primary browse species in Nowendoc.

Koalas clearly use and eat ***E. saligna*** (Sydney blue gum) at times, consistent with it being a secondary browse species.

Most evidence for the use of ribbon gums (specifically ***E. viminalis***) comes from Victoria, where it is an important browse species for koalas. *Eucalyptus viminalis* is also eaten by koalas in Southern NSW, but there are no studies in northern NSW that refer to its level of use, or for the use of ***E. nobilis***.

Although ***E. obliqua*** (messmate) may be used and sometimes eaten by koalas in Victoria, we did not find any studies that document its level of use by koalas in NSW.

We found little information in the literature about whether E¡.pauciflora (snow gum) is used or eaten by koalas. The same is true for E¡.dalrympleana (mountain gum), although two reviews suggest that this species may be used regularly and/or is a preferred food tree in some locations. One of us – Karen Marsh – has previously fed both of these species to koalas in captivity in southern NSW but did not quantify intake. Nevertheless, *E. dalrympleana* was eaten to a much greater extent than *E. pauciflora*.

We found little information about the level of use of New England blackbutt (E¡. andrewsii and E¡.campanulata), but where it was mentioned, use appeared to be relatively low and there was no mention of feeding.

Most of the published literature on the association of koalas with ironbarks (E¡. paniculata and E¡.siderophloia) suggests that they are used where available but are not generally preferred. There is limited information on whether these species are eaten.

The literature suggests that C¡.maculata (spotted gum) is sometimes used by koalas, but it is not clear how much is eaten.

There are mixed reports on the use of E¡.grandis (flooded gum) by koalas and its role as a browse species. This species is sometimes fed to koalas in captivity and wild koalas have been observed feeding in it. However, in some locations *E. grandis* is used less frequently than other available species. Despite this, there is more evidence for the use of *E. grandis* as a browse species by koalas than some of the other species on the current Coastal IFOA secondary browse tree list.

Many studies report that E¡.resinifera (red mahogany) is used by koalas. It is also sometimes eaten in quantities that suggest it may be a secondary browse species.

Table 1: Summary of literature review of secondary and currently unlisted koala browse trees for the Upper and Lower North East Subregions under the Coastal IFOA

Species	Type of evidence	Study location	Findings	Reference
E. punctata				
	Captive feeding	Japan	*E. punctata* was eaten occasionally (<20% of the diet) by zoo koalas.	(Osawa 1993)
	Captive feeding	Sydney, NSW (some koalas from Queensland)	Koalas maintained bodyweight when they were kept exclusively on *E. punctata* during multiple captive feeding experiments. High nutritional value in terms of nitrogen balance and energy yield has been thoroughly documented for this species – this is the only eucalypt for which published evidence of this nature exists.	(Cork et al. 1983, Cork and Warner 1983, Cork 1986)
	Faecal analysis (cuticle)	Sydney, NSW	*E. punctata* was a major component of koala scats in Campbelltown.	(Ellis et al. 1997)
	Faecal analysis (cuticle)	Sydney, NSW	*E. punctata* was the dominant species (66-92%) in koala faecal pellets in Campbelltown.	(Sluiter et al. 2001)
	Faecal analysis (genetic)	Blue Mountains, NSW	*E. punctata* made up more than 50% of the scat samples for six out of eight koalas.	(Blyton et al. 2023a)
	Tree use (faecal pellets)	Sydney, NSW	Out of the tree species surveyed, koala scats were found most frequently under *E. punctata*.	(Curtin et al. 2001)
	Tree use (faecal pellets)	Sydney, NSW	Relative to availability, koalas used *E. punctata* the most of all tree species surveyed.	(Phillips and Callaghan 2000)
	Tree use (daytime and nighttime radio-tracking	Sydney, NSW	All koalas preferentially used *E. punctata* relative to its availability within their home ranges.	(Taggart et al. 2023)
	Tree use (daytime observations)	Sydney, NSW	About 5% of trees were *E. punctata*, but half of koala observations were in this species.	(Smith and Smith 1990)
	Tree use (daytime radio-tracking)	Blue Mountains, NSW	Koalas used *E. punctata* more frequently than other species relative to its availability.	(Gallahar et al. 2021)
	Tree use (daytime observations)	North Coast, NSW	Forestry staff frequently reported seeing koalas in *E. punctata*.	(Reed et al. 1990)

***E. punctata* (cont.)**	Review	NSW	*E. punctata* is listed as high use in KMA2, significant use in KMA5, and irregular use in KMA1 and KMA3.	(NSW Office of Environment and Heritage 2018)
E. propinqua				
	Faecal analysis (cuticle)	North Coast, NSW	*E. propinqua* was the second most abundant species in leaf fragments in scats. Frequency was also higher than expected based on availability.	(Smith 2004)
	Faecal analysis (cuticle)	North Coast, NSW	Faecal cuticle analysis confirmed that *E. propinqua* was a primary koala feed tree species in Pine Creek State Forest. *E. propinqua* was found in 76.5% of koala scats. Radio-tracking data recorded significantly greater relative utilisation of *E. propinqua* than leaf area count.	(Radford Miller 2012)
	Faecal analysis (cuticle)	Southeast Qld	*E. propinqua* was an important dietary component according to faecal pellet analysis.	(Nyo Tun 1993)
	Captive feeding	North Coast, NSW	Carers scored the species preferences of koalas – *E. propinqua* was reported to be eaten sometimes but not consistently by some carers, and consistently but not often preferred by others.	(Smith 2004)
	Captive feeding	North Coast, NSW	*E. propinqua* is planted as a browse species for koalas at Port Macquarie koala hospital.	(Cochrane et al. 2023)
	Captive feeding	Southeast Qld	One female and one male koala were fed *E. propinqua* exclusively for one week to test methods for faecal cuticle examination.	(Ellis et al. 1999)
	Captive feeding	Southeast Qld	Zoo wildlife staff advised the authors that *E. propinqua* was a preferred browse species.	(Speight et al. 2014)
	Captive feeding	Southeast Qld	*E. propinqua* was among the most preferred browse of koalas while they were being rehabilitated in captivity.	(Nyo Tun 1993)
	Captive feeding	Japan	According to zookeepers, *E. propinqua* was classified as a species eaten occasionally (less than 20% of the diet). Other species in this group were *E. viminalis*, *E. punctata* and *E. saligna*.	(Osawa 1993)
	Tree use (night radio-tracking)	North Coast, NSW	Koalas were sometimes found in *E. propinqua* during the day and night. This species was no more or less preferred during the day than other species relative to availability.	(Law et al. 2023)
	Tree use (daytime radio-tracking)	Southeast Qld	The most frequently used tree species in Brisbane Forest Park was *E. propinqua* (33% of sightings).	(Samedi 1996)

E. propinqua **(cont.)**	Tree use (day radio-tracking)	North Coast, NSW	11.23% of koala records were in *E. propinqua*.	(Australian Museum Business Services 2011)
	Tree use (daytime observations)	North Coast, NSW	Forestry staff frequently reported seeing koalas in *E. propinqua*.	(Reed et al. 1990)
	Tree use (faecal pellets)	Northern Tablelands, NSW	Koala scats were found under 14.8% of *E. propinqua* surveyed. This is no different to what would be expected by random chance.	(Cristescu et al. 2019)
	Tree use (faecal pellets)	Noosa Shire, Qld	*E. propinqua* was the second most preferred species (use relative to availability) after *E. microcorys* (tallowwood), and was identified as a secondary species.	(Callaghan et al. 2011)
	Tree use (faecal pellets)	North Coast, NSW	*E. propinqua* was the most used species relative to availability.	(McAlpine et al. 2023)
	Tree use (faecal pellets)	Southeast Qld	*E. propinqua* had the second highest preference rating (following *E. microcorys* (tallowwood)) based on the number of faecal pellets observed per species surveyed.	(Pahl 1996)
	Tree use (faecal pellets)	North Coast, NSW	Previous tree use data from scat surveys was used to identify *E. propinqua* as a preferred species in the study area.	(Phillips et al. 2021)
	Tree use (faecal pellets)	Southeast Qld	Many of the scats located for the report were found under *E. propinqua*.	(OWAD Environment 2018)
	Tree use (faecal pellets)	Southeast Qld	Based on strike rates, *E. propinqua* fell within the group of second most preferred species.	(Biolink Ecological Consultants 2017)
	Tree use (faecal pellets)	North Coast, NSW	*E. propinqua* was statistically the highest utilised species in all pilot areas, with the exception of Clouds Creek.	(NSW Environment Protection Agency 2016)
	Tree use (faecal pellets)	Southeast Qld	Koalas showed high use of *E. propinqua*.	(Lollback et al. 2018)
	Review	NSW and Qld	*E. propinqua* is consistently one of the most preferred browse species in south-east Queensland and north-east NSW, although caution must be used because most studies are based on diurnal observations or distributions of faecal pellets.	(Melzer and Houston 2001)

	Review	North Coast, NSW	*E. propinqua* was among one of the preferred species of koalas in the Dorrigo area.	(Ede et al. 2016)
	Review	Australia	*E. propinqua* listed as a species preferred by koalas.	(Bryan 1997)
	Review	Qld	*E. propinqua* classified as a high use species.	(Runge et al. 2021)
E. propinqua **(cont.)**	Review	NSW	*E. propinqua* classified as high use in KMA1 and significant use in KMA2.	(NSW Office of Environment and Heritage 2018)
E. moluccana				
	Captive feeding	Southeast Qld	*E. moluccana* was one of the species fed to zoo koalas, but there is no information on how much they ate.	(Adam et al. 2022)
	Review	Northern Tablelands, NSW	*E. moluccana* listed as a main food tree in the Northern Tablelands.	(Ede et al. 2016)
	Review	NSW	*E. moluccana* listed as significant use in KMA1 and KMA2, and irregular use in KMA4.	(NSW Office of Environment and Heritage 2018)
E. largeana				
	No published literature			
E. radiata				
	Faecal analysis (genetic)	Southern Vic	*E. radiata* was a possible major component in faecal samples from several translocated koalas in Victoria, however markers were unable to distinguish it from *E. falciformis* and in some cases, *E. obliqua*.	(Blyton et al. 2023a)
	Captive feeding	USA	Zoo koalas ate relatively little *E. radiata* compared to other eucalypt species.	(Higgins et al. 2011)
	Captive feeding	Southern Tablelands, NSW	Captive koalas avoided eating *E. radiata* mature and epicormic leaves.	(Lane et al. 2023)
	Tree use (daytime observation)	South Gippsland, Vic	Koalas in Victoria preferred *E. ovata*, but if that species was excluded, they preferred *E. obliqua* over *E. radiata*. Consumption of *E. obliqua* and *E. radiata* was initiated by the defoliation of *E. ovata* by koalas; this dietary switch was associated with evidence of malnutrition.	(Martin 1985)

	Review	NSW	*E. radiata* documented as high use in KMA4, significant use in KMA2, and irregular use in KMA5.	(NSW Office of Environment and Heritage 2018)
E. acaciiformis				
	Tree use (daytime observations)	Northern Tablelands, NSW	Koalas were found most commonly in *E. acaciiformis* (rather than *E. stellulata* or *E. pauciflora*) at Nowendoc. This was considered to be the primary browse species.	(Clarke 1983)
E. acaciiformis **(cont.)**	Tree use (daytime observations)	North Coast, NSW	Forestry staff occasionally reported seeing koalas in *E. acaciiformis*.	(Reed et al. 1990)
	Review	NSW	*E. acaciiformis* listed as high use in KMA4.	(NSW Office of Environment and Heritage 2018)
E. saligna				
	Faecal analysis (cuticle)	North Coast, NSW	*E. saligna* was one of the main species detected in scats from koalas in Pine Creek State Forest.	(Radford Miller 2012)
	Faecal analysis (genetic)	Blue Mountains, NSW	*E. saligna* was identified in the scats of some koalas.	(Blyton et al. 2023a)
	Captive feeding	North Coast, NSW	Koala carers reported that *E. saligna* was eaten sometimes but not consistently.	(Smith 2004)
	Captive feeding	Japan	*E. saligna* was eaten occasionally (<20% of the diet) by zoo koalas.	(Osawa 1993)
	Tree use (faecal pellets)	North Coast, NSW	*E. saligna* was ranked with the secondary group of eucalypts for use relative to availability.	(McAlpine et al. 2023)
	Tree use (daytime observations)	North Coast, NSW	*E. saligna* was the most frequent species in which forestry staff reported seeing koalas.	(Reed et al. 1990)
	Tree use (daytime radio-tracking)	Blue Mountains, NSW	Some koalas used *E. saligna* and others did not. In general, use was low relative to availability.	(Gallahar et al. 2021)
	Review	NSW	*E. saligna* listed as significant use in KMA1 and irregular use in KMA2.	(NSW Office of Environment and Heritage 2018)
E. viminalis				

E. viminalis **(cont.)**	Feeding observations (radio-tracking)	Phillip Island, Vic	Free-ranging koalas ate almost half of their meals in *E. viminalis*.	(Marsh et al. 2014)
	Captive feeding	Southern Vic	Koalas ate variable amounts of *E. viminalis* foliage depending on the nutritional composition.	(Moore et al. 2005, Marsh et al. 2007)
	Captive feeding	USA	*E. viminalis* was one of the least preferred species for zoo koalas.	(Higgins et al. 2011)
	Faecal analysis (cuticle wax)	Southern Vic	Diets of wild koalas contained more than 80% *E. viminalis*.	(Brice et al. 2019b)
	Faecal analysis (genetic)	Southern Vic	*E. viminalis* was a major component of the diets of some koalas.	(Blyton et al. 2023a)
	Captive feeding	Southern Tablelands, NSW	Captive koalas readily ate *E. viminalis* epicormic leaves and sometimes ate mature leaves.	(Lane et al. 2023)
	Tree use (daytime observations)	Southern Vic	*E. viminalis* was the most preferred species relative to availability.	(Hindell et al. 1985, Hindell and Lee 1987)
	Tree use (faecal pellets)	Ballarat, Vic	*E. viminalis* was used preferentially by koalas.	(Prevett et al. 2001)
	Tree health	SA, Vic	Koalas can reach high densities and defoliate *E. viminalis* in some populations.	(Masters et al. 2004, Whisson and Ashman 2020)
	Review	NSW	*E. viminalis* classified as high use in KMA2, KMA4 and KMA5 and irregular use in KMA1 and KMA3.	(NSW Office of Environment and Heritage 2018)
E. nobilis				
	Acoustic surveys	North Coast, NSW	Koalas were absent from sites with a high cover of *E. nobilis*.	(Law et al. 2018)
	Review	North Coast, NSW	*E. nobilis* may be one of the preferred trees in the Armidale region.	(Ede et al. 2016)
	Review	NSW	*E. nobilis* is listed as high use in KMA4.	(NSW Office of Environment and Heritage 2018)
E. obliqua				

E. obliqua **(cont.)**	Faecal analysis (cuticle wax)	Southern Vic	*E. obliqua* can form a large component of the diet of some individuals in Victoria, however this study took place in the context of overabundance and associated defoliation and dieback of preferred trees. Many individuals in this population refused to eat *E. obliqua.*	(Brice et al. 2019b)
	Faecal analysis (genetic)	Southern Vic	*E. obliqua* was commonly found in scats of translocated Victorian koalas.	(Blyton et al. 2023a)
	Captive feeding	Southern Vic	Some Victorian individuals were maintained exclusively on *E. obliqua* for many days. However, detailed nutritional analysis showed that these koalas were in negative nitrogen balance and acquired approximately half the metabolizable energy that they gained from feeding on their preferred food tree, *E. viminalis*. Long term survival on this species alone would be impossible.	(Marsh et al. 2021a) Moore and Blyton, *unpubl.*
	Tree use (daytime observation)	South Gippsland, Vic	Koalas in Victoria preferred *E. ovata*, but if that species was excluded, they preferred *E. obliqua* over *E. radiata*.	(Martin 1985)
	Tree use (daytime radio-tracking)	Ballarat, Vic	*E. obliqua* was strongly avoided at one site, although it may have been preferred at another.	(Santamaria et al. 2005)
	Tree use (faecal pellets)	Ballarat, Vic	Although *E. obliqua* was not used preferentially by koalas near Ballarat, they were more likely to use it at some sites than others.	(Prevett et al. 2001)
	Review	NSW	*E. obliqua* listed as significant use in KMA3 and irregular use in KMA4 and KMA5.	(NSW Office of Environment and Heritage 2018)
E. pauciflora				
	Captive feeding	NSW	*E. pauciflora* is sometimes fed to captive koalas, but there is no information on how much is eaten.	(Hume and Esson 1993)
	Tree use (daytime observations)	Northern Tablelands, NSW	Koalas used *E. pauciflora* the least out of the available eucalypt species in Nowendoc.	(Clarke 1983)
	Review	NSW	*E. pauciflora* listed as significant use in KMA4 and irregular use in KMA5.	(NSW Office of Environment and Heritage 2018)

E. dalrympleana	Review	NSW	*E. dalrympleana* listed as high use in KMA4 and irregular use in KMA5.	(NSW Office of Environment and Heritage 2018)
	Review	Northern Tablelands, NSW	Studies in Armidale indicate that *E. dalrympleana* is a preferred food tree.	(Ede et al. 2016)
E. andrewsii				
	Tree use (daytime observations)	North Coast, NSW	Forestry staff occasionally reported seeing koalas in *E. andrewsii*.	(Reed et al. 1990)
	Review	NSW	*E. andrewsii* listed as irregular use in KMA4.	(NSW Office of Environment and Heritage 2018)
E. campanulata				
	Tree use (faecal pellets)	Northern Tablelands, NSW	Koala scats were present under 4.4% of *E. campanulata* trees surveyed.	(Cristescu et al. 2019)
	Review	NSW	*E. campanulata* listed as low use in KMA4.	(NSW Office of Environment and Heritage 2018)
	Review	NSW	*E. campanulata* listed as low use in KMA4.	(NSW Office of Environment and Heritage 2018)
Additional (currently unlisted) species				
E. paniculata				
	Faecal analysis (genetic)	Blue Mountains, NSW	There was no evidence that any of the koalas were feeding on *E. paniculata,* but it was very uncommon and unevenly distributed at the site.	(Blyton et al. 2023a)
	Captive feeding	North Coast, NSW	*E. paniculata* was one of the species fed to koalas in captivity at Coffs Harbour Zoo, but they did not report how much was eaten.	(Hume and Esson 1993)
	Tree use (night radio-tracking)	North Coast, NSW	Koalas were sometimes found in *E. paniculata* during the day, but rarely at night. This species was no more or less preferred during the day than other species relative to availability.	(Law et al. 2023)

	Tree use (daytime observations)	Sydney, NSW	*E. paniculata* was used less frequently than expected.	(Smith and Smith 1990)
	Tree use (daytime observations)	Sydney, NSW	Koalas were reported in *E. paniculata* on at least three occasions, but it was under-exploited relative to its abundance.	(Smith and Smith 2000)
	Review	Australia	*E. paniculata* listed as a species utilised by koalas.	(Bryan 1997)
	Review	Qld	*E. paniculata* classified as a medium use species.	(Runge et al. 2021)
E. paniculata **(cont.)**	Review	NSW	*E. paniculata* classified as high use in KMA2.	(NSW Office of Environment and Heritage 2018)
E. siderophloia				
	Tree use (faecal pellets)	Southeast Qld	*E. siderophloia* was identified as a secondary eucalypt species.	(Callaghan et al. 2011)
	Tree use (faecal pellets)	North Coast, NSW	*E. siderophloia* had low proportional use relative to availability.	(McAlpine et al. 2023)
	Tree use (faecal pellets)	Southeast Qld	Koala scats were found under 67% of surveyed *E. siderophloia* trees.	(Watkins et al. 2021)
	Tree use (faecal pellets)	Southeast Qld	*E. siderophloia* fell within the group of least preferred species based on strike rates.	(Biolink Ecological Consultants 2017)
	Tree use (faecal pellets)	Northern Tablelands, NSW	Koala scats were found under 12.5% of *E. siderophloia* surveyed. This is no different to what would be expected by random chance.	(Cristescu et al. 2019)
	Tree use (daytime radio-tracking)	Southeast Qld	Across the sites assessed, *E. siderophloia* was locally preferred but not widely available.	(Thompson 2006)
	Review	Qld	*E. siderophloia* classified as a medium use species.	(Runge et al. 2021)
	Review	NSW	*E. siderophloia* classified as low use in KMA2 and significant use in KMA1.	(NSW Office of Environment and Heritage 2018)
C. maculata				
	Captive feeding	Southeast Qld	*C. maculata* is fed to koalas in captivity, but there is no information on how much is eaten.	(Adam et al. 2022)

***C. maculata* (cont.)**	Captive feeding	North Coast, NSW	*C. maculata* was one of the species fed to koalas in captivity at Coffs Harbour Zoo, but they did not report how much was eaten.	(Hume and Esson 1993)
	Faecal analysis (cuticle)	Southeast Qld	There was no evidence of *C. maculata* in koala scats.	(Nyo Tun 1993)
	Tree use (faecal pellets)	Northern Tablelands, NSW	Koala scats were found under 16% of *C. maculata* trees surveyed. This is no different to what would be expected by random chance.	(Cristescu et al. 2019)
	Tree use (daytime observations)	North Coast, NSW	Forestry staff occasionally reported seeing koalas in *C. maculata*.	(Reed et al. 1990)
	Review	Qld	*C. maculata* classified as a medium use species.	(Runge et al. 2021)
	Review	NSW	*C. maculata* classified as irregular use in KMA1, KMA2 and KMA3.	(NSW Office of Environment and Heritage 2018)
E. grandis				
	Captive feeding	North Coast, NSW	*E. grandis* was one of the species fed to koalas in captivity at Coffs Harbour Zoo, but they did not report how much was eaten.	(Hume and Esson 1993)
	Captive feeding	North Coast, NSW	Carers scored the species preferences of koalas – *E. grandis* was eaten sometimes, but not consistently.	(Smith 2004)
	Faecal analysis (cuticle)	North Coast, NSW	*E. grandis* was found in 22.5% of scats in Pine Creek State Forest. Radio-tracking data recorded significantly greater relative utilisation of *E. grandis* than leaf area count.	(Radford Miller 2012)
	Feeding observations (radio-tracking)	North Coast, NSW	2.4% of observed feeding events were in *E. grandis*.	(Melzer and Houston 2001)
	Faecal analysis (genetic) from captive feeding		Reported multiple BLAST hits for *E. grandis* in scats from captive koalas. This species was commonly fed to them. However, this does not constitute evidence for consumption of *E. grandis* specifically, but rather for *Eucalyptus*. *E. grandis* was the first eucalypt to have its genome sequenced and for many years was the only eucalypt represented in sequence databases. There is no evidence that the sequences identified are specific to this species.	(Schultz et al. 2018)

E. grandis **(cont.)**	Tree use (day radio-tracking)	North Coast, NSW	20.8% of koala records were in *E. grandis*.	(Australian Museum Business Services 2011)
	Tree use (daytime observations)	North Coast, NSW	Forestry staff frequently reported seeing koalas in *E. grandis*.	(Reed et al. 1990)
	Tree use (faecal pellets)	Noosa Shire, Qld	*E. grandis* had a low "strike rate" relative to availability.	(Callaghan et al. 2011)
	Tree use (faecal pellets)	North Coast, NSW	*E. grandis* was utilised by koalas, but not as commonly as some other species.	(Lunney et al. 2000)
	Tree use (faecal pellets)	North Coast, NSW	Koala scats were found to occur significantly less often than expected below flooded gum.	(Smith 2004)
	Tree use (faecal pellets)	North Coast, NSW	*E. grandis* was ranked as a preferred species relative to availability.	(McAlpine et al. 2023)
	Review	Australia	*E. grandis* listed as a species preferred by koalas.	(Bryan 1997)
	Review	NSW	*E. grandis* classified as significant use in KMA1.	(NSW Office of Environment and Heritage 2018)
E. resinifera				
	Faecal analysis (cuticle) from captive feeding	Brisbane, Qld	Captive koalas consumed *E. resinifera* in combination with other eucalypt species, and it accounted for up to 50% of the leaf cuticles present in scats for some koalas on some days.	(Ellis et al. 1999)
	Faecal analysis (cuticle)	North Stradbroke Island, Qld	*E. resinifera* accounted for 7.4% of trees used by radio-tracked koalas. The species was present in 22.5% of scats and the abundance was around 10% on average.	(Cristescu et al. 2013)
	Faecal analysis (cuticle)	North Stradbroke Island, Qld	Faecal cuticle analysis revealed that koala diets were approximately 10-15% *E. resinifera*.	(Woodward et al. 2008)
	Faecal analysis (cuticle)	North Coast, NSW	*E. resinifera* was found in 6.9% of scats despite being relatively rare in the forest. Overall, it represented only a small proportion of the diet.	(Radford Miller 2012)
	Faecal analysis (cuticle)	North Stradbroke Island, Qld	4.4% of identified leaf cuticle fragments were *E. resinifera*.	(Melzer et al. 2014)

E. resinifera **(cont.)**	Faecal analysis (cuticle)	Southeast Qld	*E. resinifera* was often among the top three preferred browse species of wild koalas according to faecal cuticle analysis.	(Nyo Tun 1993)
	Tree use (faecal pellets)	Coffs Harbour, NSW	In active sites, scats were found under 10% of *E. resinifera* trees.	(Lunney et al. 2000)
	Tree use (faecal pellets)	Brisbane, Qld	According to scat surveys, *E. resinifera* was used infrequently by koalas in periurban remnant forest.	(Lollback et al. 2018)
	Tree use (day radio-tracking)	North Coast, NSW	Koalas were observed in *E. resinifera* during daylight on 5.6% of occasions.	(Law et al. 2023)
	Tree use (faecal pellets)	Southeast Qld	Based on tree use, *E. resinifera* was classed as a secondary species, with koalas actively selecting for it.	(Callaghan et al. 2011)
	Tree use (faecal pellets)	North Coast, NSW	*E. resinifera* was ranked as a secondary species based on use relative to availability.	(McAlpine et al. 2023)
	Tree use (day radio-tracking)	North Coast, NSW	Koalas were occasionally observed in *E. resinifera*.	(Australian Museum Business Services 2011)
	Review	Australia	*E. resinifera* listed as a species utilised (but not necessarily preferred) by koalas.	(Bryan 1997)
	Review	NSW	*E. resinifera* is classified as high use in KMA1 and significant use in KMA2.	(NSW Office of Environment and Heritage 2018)
	Review	NSW	Multiple authors suggested that *E. resinifera* was occasionally eaten by koalas.	(Clarke 1983)

3. **Consultation with experts**

There were no additional literature sources identified through our consultation with the ten experts listed in Appendix 1, although many experts mentioned unpublished data or insights from their own work. Where these insights arise from direct observations of koala tree use evidence, we consider these to be relevant to our assessment, regardless of whether the data are 'published'. We have differentiated between anecdotal or secondhand knowledge relayed by experts and first-hand experience and weighted expert input accordingly in making our final suggestions. There are very limited avenues for publication of stand-alone koala tree-use data and the scientific literature will generally only capture tree use data where it is included in reports of hypothesis-driven investigations; databases that capture wildlife observations do not capture accompanying details such as tree species use. This fact should not be used to justify the dismissal of valuable expert experience. By far the largest dataset of koala scat surveys in existence is as yet unpublished but our conclusions are influenced by insights from it, as relayed during our interviews.

Multiple experts cited evidence from McAlpine et al (2023) and Radford Miller (2012) to support their experience with the tree species under discussion. We therefore review these two studies in more detail at the end of this section. We summarise the discussions below and in Table 2.

In discussions with experts, we covered most of the trees on the current Coastal IFOA koala browse list, and sometimes additional candidate food trees as well, in addition to the species highlighted by the NRC. No extensive discussions took place around E¡. robusta (swamp mahogany). Everybody agreed that this is unambiguously a primary koala food tree, however much of it is already protected in the Coastal Swamp Sclerophyll Threatened Ecological Community, and it is rarely impacted by forestry harvesting operations.

There was unanimous agreement that E¡.microcorys (tallowwood) is a primary koala food tree, based on extensive tree use (scat surveys and day/night radiotracking) and diet composition studies. One particular point that was raised during discussions of *E. microcorys* (tallowwood) is that it is one of four species with a timber quota and is thus highly valuable and sought-after, and that it is not simple to regenerate and much regeneration is from lignotubers. One expert also has data suggesting that the use of some other species is elevated when it is growing near tallowwood. This has two implications for Coastal IFOA protocols – first, the value of other species (secondary and potentially other primary koala browse trees) may decline if insufficient *E. microcorys* (tallowwood) is retained at harvest; and second, the value of the forest patch, as a whole, to koalas may decline if insufficient *E. microcorys* (tallowwood) is retained. In counterpoint to this, Law et al. (2018) did show that this species remained the most widespread (which does necessarily mean it is the most abundant - on average it represented a small portion of the canopy ~4%; Law et al. 2022) species in their study, occurring at a majority of the 171 previously harvested sites acoustically surveyed for koala presence in NE NSW. It should be noted that site selection in that study was guided by a habitat model (Law et al. 2017) which in turn was strongly influenced by the predicted abundance of *E. microcorys* (tallowwood). Ongoing analysis from permanent growth plots appears to show that tallowwood basal area can rapidly recover after fire and harvesting events (Law, unpubl). This is also consistent with earlier work by King (1985) which observed strong natural regeneration of *E. microcorys* (tallowwood) in certain wet sclerophyll forests on the NSW mid-north coast.

All experts also agreed that E¡.tereticornis (forest red gum) is a primary koala food tree. Several experts provided some specific examples. One was that around Lismore and the Richmond Ranges, habitat dominated by this species can support 2-3 koalas/ha, producing indications of overbrowsing and indeed, management interventions are currently being considered. There are similar koala densities in *E. tereticornis* (forest red gum) on fertile basalt soils along rivers around Casino, although it is less used away from rivers. Another example was the use of *E. tereticornis* (forest red gum) by koalas in state forests in the Clarence Valley. However, it was commonly observed that *E. tereticornis* (forest red gum) often occurs at low densities in state forests, and it is less frequently impacted by most harvesting operations than *E. microcorys* (tallowwood).

There was more nuanced discussion around some of the other red gum species, but these species again may be less commonly impacted in state forests. Based on their experience, several experts indicated that E¡.glaucina and E¡.parramattensis are likely important koala food trees, while one commented that E¡.bancroftii was especially valuable. One expert suggested that *E. parramattensis* is a primary browse species on the Tomago sandbeds (Port Stephens) but not important elsewhere. Eucalyptus. seeana (narrow-leaved red gum) sometimes experiences significant koala use but is less preferred than *E. tereticornis*. Eucalyptus.amplifolia (cabbage gum) may be a secondary browse tree but is not commonly encountered across most of the Upper and Lower Northeast Subregions.

There was widespread support for the idea that grey gums (E¡.punctata?E¡.propinqua. and E¡.canaliculata) are more valuable to koalas than is currently recognised by their secondary status on the Coastal IFOA koala browse tree list. Several experts noted that *E. propinqua* (small-fruited grey gum) (or *E. punctata* south of Taree) is particularly valuable to koalas in the absence of tallowwood because they are often present in reasonable numbers even when tallowwood is not abundant. Some referred to Radford Miller's (2012) study from Pine Creek as evidence for extensive use of *E. propinqua* (small-fruited grey gum), stating that grey gums are an important koala resource and, while not the equal of *E. microcorys* (tallowwood), they are a step above most other secondary food trees. Most experts thought that the value of grey gums sits somewhere between that of the primary and secondary browse species and all experts to whom it was proposed responded positively to placing grey gums in an intermediate tier between primary and secondary browse species

Few experts had specific experience with the grey boxes (E¡.moluccana.and.E¡. largeana). For those who did, they either recognised these species as secondary browse or thought they had little value to koalas. For example, based on extensive tree use data, one expert stated that *E. moluccana* is categorically not a preferred species, although it supports lots of brushtail possums (but not koalas) in the Hunter Valley.

Again, there was little direct experience with the peppermints (E¡.radiata.and.E¡. acaciiformis) in the context of northern NSW, although one expert noted that.*E. acaciiformis* was the most preferred species by koalas at Nowendoc, a very high-elevation site, during Andrew Krockenberger's PhD work.

There were mixed views among experts about the value of E¡.saligna (Sydney blue gum) to koalas. Where they believed that it was important, most experts referred us to Radford Miller (2012) or to radiotracking work by Rob Close and John Pile in Bongil Bongil and Pine Creek State Forests. One expert also pointed to widespread perceptions of the value of *E. saligna* as an important koala food tree, including its planting by RMS at Ballina as part of koala habitat regeneration works. It is also grown in koala browse plantations on occasion and koalas at Currumbin are fed it routinely. Note, however, that one of us – Ben Moore – has observed koalas from Campbelltown to consistently reject plantation *E. saligna* when offered it during captivity. Others commented that they had not personally observed strong evidence of koala use of *E. saligna*, even though it is widespread in some areas. Where it is used (note: use does not necessarily indicate feeding), this use is influenced by the nearby presence of *E. microcorys* (tallowwood), and use is not maintained in the absence of other more valuable koala food tree species. For example, one expert had observed that at Wild Cattle Creek, in forest dominated by *E. saligna* (Sydney blue gum), *E. microcorys* (tallowwood) and very large *Allocasuarina torulosa* (forest she-oak), koala tree use was overwhelmingly directed towards *E. microcorys* (tallowwood).

While many experts acknowledged that E¡.viminalis (ribbon gum) can be an important browse tree for koalas in southern Australia and in coastal regions, most did not know whether it was used in northern NSW. One expert drew upon a very extensive dataset of tree use from throughout the koala's range to emphasise that away from coastal Victoria and South Australia, *E. viminalis* is not widely used by koalas. One expert suggested that there are locations at Boorlong, north of Armidale, where there are koalas using *E. viminalis*. In keeping with the literature, experts could offer no evidence that koalas browse on E¡.nobilis (ribbon gum).

Experts who commented on E¡.obliqua (messmate) and E¡.pauciflora (snow gum) suggested that there was limited or weak evidence for their use by koalas in northern NSW. They were also unsure about the role of E¡.dalrympleana (mountain gum).

Consistent with the literature, most experts commented that there was no strong evidence for koala use of New England blackbutts (E¡.andrewsii and E¡.campanulata). One expert stated that, despite extensive field surveys, they had found no koalas in *E. andrewsii* or *E. campanulata*. Furthermore, there are very few koalas despite abundant *E. andrewsii* in the Styx River. Another said that both species occur on the edge of the northern Tablelands and, even when occurring in association with *E. microcorys* (tallowwood), they are not used by koalas.

Experts who had direct experience with ironbarks (particularly E¡.siderophloia and E¡. paniculata) did not think these species were valuable koala food trees. Two commented that ironbarks are used relatively uncommonly by koalas during both the day and night, and they are eaten only occasionally.

The general view was that C¡.maculata (spotted gum) is not particularly important to koalas, although some experts provided examples of its use. One expert referred to recent work by McAlpine et al. (2023) showing that *C. maculata* (spotted gum) is used by koalas (not necessarily evidence of extensive use as browse, although they had seen koalas eating it). This expert suggested it is more important in some areas than others and plays an important structural/shelter role due to its dense canopy. Another expert had found lots of koalas in places with spotted gum (both *C. maculata* and *C. henreyi*). One expert noted that koala carers at Taree swear by *C. maculata* (spotted gum) as a favoured browse species for koalas in care, but it was not an important browse tree for koalas in their experience with radio-tracking.

Many experts had not personally observed strong use of E¡.grandis (flooded gum) by koalas. However, several noted that koalas inhabit *E. grandis* (flooded gum) plantations at Pine Creek and Goonegerry SF, although these may only be useful where they are growing in association with tallowwood or grey gums. Some experts cited Radford Miller (2012) as evidence that *E. grandis* (flooded gum) was a secondary browse tree, and one also mentioned that it is sometimes fed to koalas in captivity. Furthermore, *E. grandis* (flooded gum) has been included in a list of koala food trees for the proposed Great Koala National Park for the purpose of stratifying koala habitat.

Several experts also mentioned that, in their experience, E¡.resinifera (red mahogany) was used by koalas more frequently than many of the other species on the secondary browse list. This included data from both radiotracking (day and night) and scat surveys.

A majority of the ten experts recognised that there were potential environmental risks with expanding the list of primary food trees. This was directly linked to the possibility that any new species might be retained in place of the economically valuable *E. microcorys* (tallowwood), which is a widely utilised browse species for koalas. The general consensus was that, when considering the addition of any new species to the list of primary koala food trees, this must be undertaken with the realisation that there is a limited "budget" for tree retention.

Review of Ph.D. thesis by Sally Radford Miller (2012)

Several experts that we spoke to pointed us to research from the Ph.D. thesis "Aspects of the ecology of the koala, *Phascolarctos cinereus*, in a tall coastal production forest in north eastern New South Wales" by Sally Radford Miller, 2012, Southern Cross University[§]. They felt that this research may have been overlooked when compiling the original list, and so we summarise its findings here. Findings for each species are also included in the literature review table (table 1).

The research was undertaken in what was then Pine Creek State Forest, south of Coffs Harbour. The work is valuable because it is based not only on observations of tree use

[§] Thesis available at https://researchportal.scu.edu.au/esploro/outputs/doctoral/991012947800502368 during radiotracking, but also undertook faecal cuticle analysis. This technique views preparations from faecal samples under a microscope and identifies and sometimes quantifies distinctive fragments of leaf cuticle in faeces, assigning them to species consumed. We emphasise that this approach does not avoid any of the uncertainties associated with molecular faecal diet composition analysis, and may be significantly more affected.

In contrast to the molecular method, classification of cuticle marker fragments is unavoidably somewhat subjective and potentially subject to user bias. It can be difficult to fully capture the variation that may occur in cuticle characteristics within a species (or even a tree), and the cuticle of some species pairs or groups simply cannot be reliably distinguished. It also does not have the advantage of the molecular approach in relying on multiple individual markers for each species. As with MFDCA, the persistence of cuticle in the faeces varies among species, and among leaf age classes. One study applied this method to green ringtail possums, *Pseudochirops archeri*, in North Queensland Rainforest. In that instance, the cuticle of *Ficus* species was entirely digested and undetectable in faeces, despite it accounting for the greatest part of feeding observations (Andrew Krockenberger pers. comm.; Jones et al. 2006).

Radford Miller (2012) analysed 102 scat samples collected during her study, representing 22 koalas. The samples were selected to match koalas whose home ranges had been assessed by vegetation plots to allow for direct comparison of diet with available species. The most commonly identified cuticle fragments (with frequency of detection and abundance of each species as a percentage of total stems) were: *E. microcorys* (tallowwood) (100%, 1.93%), *Allocasuarina torulosa* (forest she-oak) (94%. 6.66%), *E. saligna* (Sydney blue gum) (86%, 1.00%), *E. propinqua* (small-fruited grey gum) (77%, 0.33%), *E. pilularis* (blackbutt) (46%, 4.46%) and *E. grandis* (flooded gum) (22.5%, 3.44%).

Radford Miller concluded: "Faecal cuticle analysis confirmed that Eucalyptus. microcorys.(tallowwood)?E¡.saligna.(Sydney blue gum)?E¡.propinqua (small-fruited grey gum) and Allocasuarina.torulosa (forest she-oak) were the primary koala feed tree species (KFTS) in this forest with tallowwood found in 100% of faecal pellet samples analysed and the other three species each appeared in over 75% of faecal pellet samples. Koala tree preferences, as determined by diurnal radio-tracking records and dietary analysis were correlated for the top six tree species used as refuge and forage: these included the four KFTS plus E¡.pilularis (blackbutt) and E¡.grandis.(flooded gum). Koalas also foraged on a range of non-eucalypt tree species, and some non-eucalypt species were used primarily for refuge, as these did not form a large part of the diet".

Despite the conclusions above, we do not consider this study to support the use of E. pilularis (blackbutt) and E¡.grandis (flooded gum) as secondary browse species because although they were consumed, they were detected in relatively small fractions of scats (46 and 23%) despite high availability in the habitat. Ellis et al. (1999) showed that cuticle could be detected in koala scat for 3 to 4 days after the consumption of a species. To put Radford Miller's data in light of that observation, 77% of scats showed that koalas had not consumed *E. grandis* (flooded gum) in the three days previous. This would be consistent with consumption of some amount of *E. grandis* (flooded gum) as little as once per fortnight – despite this being a highly abundant and large tree with a dense canopy and cool trunk offering high quality shelter. Similarly, the rates of cuticle detection for *E. pilularis* (blackbutt) imply consumption only about every fifth day.

The observation of high rates of use of Allocasuarina at this site are frequently cited, however we have found this genus to be very sparingly used, if at all, in our study of koala diets in Queensland, based upon the successful application of molecular faecal diet composition analysis to 344 koala scats (Moore et al. 2023). It is quite likely that the distinctive cuticles of this genus, in which the “needles” are in fact photosynthetic branchlets, are particularly persistent through digestion.

<u>Recent study by McAlpine et al. (2023)</u>

Another major recent study of koala tree use on the north coast of NSW (also included in the literature review table) which was referred to by multiple interviewees was the study by McAlpine et al. (2023). The study undertook koala scat surveys at >9000 trees from 302 randomly selected sites across four LGAs. The conclusion was that the dominant factor associated with habitat use and koala occurrence was the distribution of five *Eucalyptus* species. That first ranking comprised E¡.propinqua.(small-fruited grey gum)?.E¡.robusta.(swamp mahogany)?E¡.tereticornis.(forest red gum)?.E¡.microcorys.(tallowwood) and E¡.grandis.(flooded gum). Notably, *E. grandis* (flooded gum) was used significantly more in the Lismore LGA than in three other LGAs. Species ranked in a second tier (equivalent to secondary browse trees) were E¡.saligna (Sydney blue gum)?.E¡.pilularis.(blackbutt), *E. carnea* (thick-leaved mahogany), E¡.resinifera (red mahogany) and *E. dunnii* (Dunn's white gum). Third-ranked eucalypts were E¡.siderophloia (ironbark) and E¡.acmenoides.(white mahogany).

One expert did point out that the study by McAlpine et al (2023) was strongly weighted towards koalas on private lands, often used for grazing, and with low elevation, gentle slopes and better soils. It included relatively fewer sites in state forests and national parks, and the patterns may not hold precisely across these different land tenures, in part because of the different vegetation communities present. They also observed that the rates of use of E¡.microcorys (tallowwood) might be overemphasised in that study, relative to the situation in natural forest communities, because of its widespread use in windbreaks.

Table 2: Summary of expert rankings of koala browse trees

Species	A	B	C	D	E	F	G	H	I	J	K	L
E. microcorys	1		1	1	1	1	1	1	1	1	1	1
E. robusta				1	1		1			1		1
Red gums				1	1					1		
E. tereticornis			1			1	1		1			1
E. seeana			2*				N		2*			
E. glaucina							1		2			
E. bancroftii			N				-		1			
E. amplifolia			N	2*			N		2			
E. parramattensis				2*					2*			
Grey gums	1*		1*	1*	1*	1*	1*	1	1*	1*		
E. propinqua											1	1
E. punctata												
C. maculata	2*	N	2*				N	N	N	N		
Ironbarks	-	-	N	N			N		N	2		N
Grey boxes												
E. moluccana					2	-	N	N	1	-		
E. largeana				2*	2	-	N	N	1	-		
Peppermints												
E. radiata				N	-	-	N	N	-	-		
E. acaciiformis				2*	-	-	N	N	-	-		
E. saligna	2*		2*	2	2	2?	N			N	1	2
E. grandis	-	2	2*	2	2	2?	N	2	2*	N	N	1
E. nobilis				N			N	-	-	N		
E. viminalis			2*	2	2		N	-	-	2		
E. obliqua				N	N	N	N	N	N	N		
E. pauciflora				N	N	N	N	N	N	N		
E. dalrympleana			-	-	2*		N	2	-	-		
New England Blackbutts												
E. andrewsii			-	N	N	-	N	-	N	-		
E. campanulata			-	N	N	-	N	-	N	-		
E. resinifera			Assoc-iated tree	2	2*				N	2	N	2
E. acmenoides				2	2*				N			N
Brush box							2		2*			
Turpentine							2					
E. laevopinea								2				
E. pilularis								-				2
E. carnea												2
E. dunnii												2

Key:

1 Should be primary

1* Should be primary but not as important as current primaries

2 should be secondary

2* locally used

N not a significant koala browse species

- No opinion

Discussion

Suggested status for Koala Browse Trees

Abundant evidence shows that koalas use a diverse range of trees, including non-eucalypts. However much of this evidence is drawn from daytime observations and/or scat counts, and this does not necessarily imply significant consumption of browse, even if koalas do "nibble" at foliage while sheltering in or passing through trees.

Diet composition analysis provides firmer evidence of the use of trees for browsing and the story emerging from these studies is also that koalas often have diverse diets. Interpreting these data quantitatively is challenging for two reasons.

First, traces of food trees can persist in faeces for several days after consumption (this has been quantified for cuticle and a similar pattern is likely for DNA) meaning that even relatively infrequent consumption of a species can produce high frequencies of detection in scat. Any species consumed on more than every second day is likely to be present in most or all scats. Second, quantification based upon the abundance of markers (cuticle or DNA) in scat is biased towards less digestible species.

Nonetheless, after considering published data and expert experience, a sensible ranking of species has emerged (table 3).

Proposed additional classification in listings: Primary – Level 2

Notably, our assessment identified three species of grey gum that are important browse species in comparison to those listed as secondary species, but not as important as those currently listed as primary species. In table 3 we suggest that the grey gums be classified on a separate tier between the existing primary and secondary browse trees (referred to in this advice as **Primary – Level 2**).

Under the proposed model, retention would first be directed towards existing primary browse trees, then if these are unavailable or exhausted, towards the grey gums as Primary – Level 2 species, and then in turn, to the secondary browse trees.

Further rationale for this approach in relation to risks associated with reduced realised retention of primary browse trees currently on the list – particularly *E. microcorys* (tallowwood) – is discussed further in the next section on environmental risks. We also note this scheme received broad support from the experts to whom it was presented.

Table 3: Suggested classification of koala browse trees for the Upper and Lower North East Coastal IFOA subregions

Species	Current status	Suggested status and reasoning behind any changes
E. microcorys (tallowwood)	Primary	Primary
E. robusta (swamp mahogany)	Primary	Primary
E. tereticornis (forest red gum)	Primary	Primary
E. glaucina (slaty red gum)	Primary	Primary
E. seeana (narrow-leaved red gum) + hybrids	Primary	**Secondary** – no literature or expert support for retention as primary; large SAT survey database suggests it has little to no value

Species	Current status	Suggested status and reasoning behind any changes
Other red gums (*E. bancroftii*, *E. parramattensis, E. amplifolia*)	Not listed	Leave unlisted. Two conflicting expert opinions on the value of *E. bancroftii* to koalas, but regardless it does not appear to be heavily impacted by harvesting. While the other two red gums received support as secondary browse trees, this pertains only to the parts of the Port Stephens region not affected by forestry.
E. biturbinata (grey gum)	Secondary	This is a synonym for *E. punctata* and need not be listed separately
E. propinqua (small-fruited grey gum)	Secondary	**Primary – level 2**. We suggest that the grey gums be classified on a new separate tier between primary and secondary. This suggestion is based upon very extensive literature evidence for the use, koala browsing and nutritional quality of the grey gums, and of its use relative to other co-occurring primary browse trees.
E. punctata (grey gum)	Secondary	**Primary – level 2.** No evidence is available to differentiate the importance of the three grey gum species to koalas, but ample evidence from the literature supports the widespread use of both *E. propinqua* and *E. punctata*. While the species do overlap, *E. propinqua* is more common north of Taree and *E. punctata* is more common to the south.
E. canaliculata (grey gum)	Secondary	**Primary – level 2.** No evidence is available to differentiate the importance of the three grey gum species to koalas, and so we treat *E. canaliculta* as equivalent to the other two species
E. moluccana (grey box)	Secondary	Secondary – this species received little support from experts as a koala browse tree, and several felt that it had no value. However, there is some literature support for its retention, particularly on the Northern Tablelands. Observations suggest that it can support very high densities of folivorous brushtail possums (Steve Phillips; Ben Moore, *pers. obs.*) but this does not necessarily translate to koala feed value. Campbelltown koalas held in captivity at WSU have generally rejected this species (Ben Moore, *pers. obs.*).
E. largeana (Craven grey box)	Secondary	Secondary – this species also received very little expert and no literature support, however we retain it as a secondary browse tree given its restricted distribution, close phylogenetic affinity with *E. moluccana* and other box species which are used by koalas.
E. radiata (narrow-leaved peppermint)	Secondary	**Remove from list** – no support in northern NSW
E. acaciiformis (wattle-leaved peppermint)	Secondary	Secondary – this species generally received little expert support but appears to be of local value to koalas in New England, and is sometimes favoured by captive koalas. Its form

Species	Current status	Suggested status and reasoning behind any changes
		and distribution is such that it is unlikely to be targeted for harvesting, and its removal from the list would probably not detrimentally impact koala habitat quality.
E. saligna (Sydney blue gum)	Secondary	Secondary – *E. saligna* and *E. grandis* elicited some of the most variable opinions from experts. Several experts were not prepared to differentiate these species in terms of value to koalas. There is some evidence for both species that they are used as primary food trees in some locations, but perhaps not universally. Both species are sometimes utilised in koala browse plantations and in koala habitat plantations, and both can exhibit high apparent nutritional quality (e.g. Marsh et al. 2021b). However, both can include significant concentrations of formylated phloroglucinol compounds, not all of which are well characterised in terms of biological activity. These species are also notable amongst eucalypts for possessing high foliar and bark concentrations of oxalate (Ben Moore, Karen Yang *unpubl. data*), which may detrimentally affect the feed value of this species; this is the subject of ongoing research.
E. grandis (flooded gum)	Not listed	Leave unlisted. Although a majority of experts were comfortable with listing this as a secondary species and one identified it as a primary koala use tree, this seems to be underpinned by patterns of tree use and scat presence. This species does possess characteristics which favour its use as a shelter tree (large size, dense canopy). Some experts were firm that it was not used, and this included one opinion based upon thousands of SAT surveys. What direct evidence there is about feeding does not indicate that this species is commonly an important koala food tree. Furthermore, many experts felt that adequate retention is already afforded by riparian exclusions in most cases.
E. nobilis (ribbon gum)	Secondary	**Remove from list** – no evidence to support this as a significant koala browse tree
E. viminalis (ribbon gum)	Secondary	Secondary – there was more support for retaining this species on the list than for removing it, despite a general lack of evidence for its use in the Upper and Lower North East subregions. While this is the most valuable koala food tree in coastal Victoria and South Australia, trees away from the coast appear not to be used to the same extent nor to be associated with overabundance of koalas. However, it is used on the Southern Tablelands of NSW.

Species	Current status	Suggested status and reasoning behind any changes
E. obliqua (messmate)	Secondary	**Remove from list -** no evidence to support this as a significant koala browse tree in the Upper and Lower North East subregions. It is a secondary food tree in Victoria and NSW, but even there, it is demonstrably inferior nutritionally to, and less preferred than, co-occuring primary koala food trees (Blyton et al. 2019, Brice et al. 2019a, Marsh et al. 2021a, Blyton et al. 2023b)
E. pauciflora (snow gum)	Secondary	**Remove from list** – no evidence to support this as a koala browse tree
E. dalrympleana (mountain gum)	Secondary	Secondary – there is some evidence for significant use of this species, and while most experts interviewed professed no personal experience with it, others were more comfortable with retaining this species.
E. andrewsii (New England blackbutt)	Secondary	**Remove from list** – no evidence to support this as a significant koala browse tree
E. campanulata (New England blackbutt)	Secondary	**Remove from list** – no evidence to support this as a significant koala browse tree
E. siderophloia (Ironbark)	Not listed	Leave unlisted. The initial faecal molecular diet composition analysis which raised the question of whether ironbarks should be considered secondary browse trees almost certainly strongly overemphasised the importance of these trees. Koalas do feed occasionally on ironbarks, but generally not to a significant extent. Our MFDCA results from Queensland also bear this out (www.whatdokoalaseat.org). Experts consulted were nearly unanimous in rejecting the listing of ironbarks as secondary browse trees. Uncertainty around which ironbarks to list also makes listing problematic.
E. paniculata (grey ironbark)	Not listed	Leave unlisted – see above.
C. maculata (spotted gum)	Not listed	Leave unlisted, for the same reasons as for the ironbarks.
E. resinifera (red mahogany)	Not listed	**Consider listing as Secondary**. Three experts felt that this species should be listed as a secondary browse tree, one noted that it is commonly associated with koala presence, and it was strongly associated with scats in the study of McAlpine et al (2023). Moore et al. (2022) identified this as the third most frequently detected species in koala scats, and the fourth-most abundant species in terms of corrected number of reads. Its nutritional quality appears to be equivalent to several other secondary browse trees (Marsh et al. 2022) and its classification as a secondary food tree is supported by multiple sources in the literature (table 1).

Environmental Risks associated with any changes to the koala browse tree list

Any alterations to the koala browse tree list carry a potential risk of environmental impact because they may alter the mixture of trees retained after harvesting operations. Any such changes might alter the immediate and longer-term suitability of harvested coupes and the surrounding landscape to support healthy koalas. While the Koala Browse Tree List and Prescriptions are specifically designed to maximise the retention of food resources for koalas, the list might also have implications for other ecosystem attributes of relevance to koalas, such as the provision of shelter trees. It should be noted that other specific protection measures are in place to manage risks to some other species; these are not considered further in this review.

Risks might extend to other attributes of forest ecosystems, including habitat suitability for other forest fauna. Several other arboreal marsupials also directly consume the foliage of *Eucalyptus* trees, including the dietary specialist southern greater glider (*Petauroides volans*; endangered), the common ringtail possum (*Psuedocheirus peregrinus*; common) and the common brushtail possum (*Trichosurus vulpecula;* common). While each of these species are known to show preferences for the foliage of some eucalypt species over others and these preferences are known to differ amongst arboreal species (Jensen et al. 2014; Moore et al., 2004), these are not sufficiently well understood to allow us to assess the potential environmental impacts of any changes to the koala browse tree list on these species. Nevertheless, captive greater gliders and ringtail possums are known to consume some of the eucalypts that we have suggested removing from the koala browse list (e.g. *E. obliqua*, *E. radiata* and *E. andrewsii*; Foley and Hume 1987; Chilcott and Hume 1984; Gopalan 2022).

However, the extent to which these species occur within areas covered by the koala retention protocols would require further analysis. Other arboreal marsupials are also dependent on trees for nutrition (e.g. floral resources, sap) and shelter (e.g. tree hollows) and large forest owls, for example, are dependent upon healthy prey populations, which largely comprise arboreal marsupials. Once again, the relative value of different koala browse tree species for providing these ecosystem services is insufficiently well understood by us.

For koalas specifically, the main risk identified in our interviews and analysis of literature was that any alterations to the list of primary koala browse trees might reduce the realised retention of primary browse trees currently on the list, particularly *E. microcorys* (tallowwood). This would be detrimental to koalas in circumstances where the current rates of retention of this species may be marginally adequate or inadequate to support the population of koalas present.

In Appendix Two, we present a series of figures illustrating the co-occurrence of some koala browse tree species in a large vegetation plot dataset. Ideally, a similar exercise would be undertaken using plot data from state forests to better understand whether the same patterns occur in areas affected by the Coastal IFOA. Appendix 2 shows that *E. propinqua* (small-fruited grey gum) co-occurs at 24% of sites with *E. microcorys* (tallowwood), thus presenting a risk of replacement of tallowwood at 25% of tallowwood sites. Another grey gum, *E. punctata* also occurs at 7% of sites. For this reason, we have suggested that the grey gums be introduced to the koala browse tree list as an intermediate tier "**Primary - Level 2**". Existing primary browse tree species should be prioritised for retention to meet the requirements of the protocols before grey gums are retained, then followed by secondary browse trees.

There is a risk that the addition of *E. propinqua* (small-fruited grey gum) to the browse tree list might not be as beneficial to koalas as hoped. There is evidence that koalas may have an absolute requirement or at least a preference, for *E. propinqua* (small-fruited grey gum) trees of a certain size (measured as dbh). Whilst pellet counts are weaker evidence of the use of trees for feeding than faecal analysis or direct feeding observations, the empirical evidence in this case is drawn from the largest existing dataset (tens of thousands of survey points) of koala pellet counts and suggests these trees are only really used significantly above a threshold dbh of somewhere between 20 to 30cm. In this context, it is notable that the current minimum dbh requirement for tree retention under the protocols is 20 cm, which may fall below, or only just meet, such a threshold.

Although the greatest risk to retention of tallowwood and other primary browse trees arises from adding species to the primary browse tree list, adding more secondary browse trees also presents some environmental risk. This is because while Protocol 23.4.4(a) states that primary browse trees must be prioritised for retention, it also states that they must make up at least 50% of retained trees. This means that retained trees can comprise 50% primary trees and 50% secondary trees, even if more primary browse trees are available. Thus, under the current protocols, secondary trees can substitute for primary browse trees as well. This is relevant to our suggestion of adding *E. resinifera* (red mahogany) to the secondary browse tree list. Appendix 2 shows that at 27% of sites where *E. resinifera* (red mahogany) occurs, *E. microcorys* (tallowwood) is also present. However, it should be noted that in most circumstances, other secondary koala browse tree species are also likely to be present, so the addition of *E. resinifera* (red mahogany) is unlikely in practice to alter retention of *E. microcorys* (tallowwood).

Knowledge Gaps

Environmental risk to koalas of any changes to the browse tree lists can only be understood if the adequacy of existing retention requirements is understood. If the current provisions are surplus to requirements of the resident koala populations, then the environmental risk of change is relatively low. If the current provisions are marginally adequate or inadequate, then the environmental risk associated with changes that might alter the total retention of the most valuable koala browse trees could be very severe.

At present, there is a knowledge gap around the outcomes of current protocols in terms of retained quantities of browse for koalas, both in absolute terms and as a proportion of pre-harvest amounts. Ideally, browse amount should be quantified directly, rather than by using basal area as a proxy. During the previous NRC-commissioned koala research program (Natural Resources Commission, 2022; Law et al., 2022) canopy composition was assessed on the basis of canopy cover. This provided a direct index of relative foliar amounts, greatly improving over basal area, although projected foliage cover would be better, and canopy cover corrected for leaf area index (LAI), still better again**. In that study, canopy composition was similar between harvested and unharvested sites. An alternative approach is being used in the current NRC-commissioned research program, in which canopy volume and nutritional quality are being assessed in forests across three harvest history classes, using drone remote sensing. It is hoped that this approach will give more direct insight into the relative nutritional value of retained trees in harvest mosaics.

Uncertainty still surrounds the importance of some browse trees (particularly secondary browse trees) to koalas. Research continues into koala browse preferences and the nutritional consequences of what koalas eat, particularly (but not exclusively) in our labs at WSU and ANU. We emphasise the value of data that tells us about what koalas eat, rather than simply which trees they use. We also note that the use of a browse species for feeding, particularly in the context of disturbance such as harvesting, may not always indicate high nutritional quality of that species.

In the context of the coastal IFOA browse tree list for the Upper and Lower North East subregions, there is a knowledge gap surrounding the specific value of some of the red gum species other than *E. tereticornis* (forest red gum). There is also a lack of agreement about the importance of *E. saligna* (Sydney blue gum) and *E. grandis* (flooded gum). In the case of those latter two species, one of us is investigating whether oxalate may provide a partial explanation for the apparently fairly low rates of use of what appear to be nutritionally good trees. Regardless, these are clearly not primary food trees, and in the case of *E. grandis* (flooded gum), many experts felt that adequate retention is already afforded by riparian exclusions in most cases.

Despite clear knowledge gaps, koala diets are better understood than the diets of other eucalypt folivores that inhabit state forests, including the endangered southern greater glider. Until more is understood about their dietary requirements, it will remain difficult to assess how the current koala browse tree list or any suggested changes impact habitat suitability for these species.

** "Canopy cover" refers to the total area of ground covered by the vertical projection of a tree's crown, including both leaves and branches, while "projected foliage cover" specifically measures the area of ground covered only by the vertical projection of the leaves, excluding the bare branches within the crown. Leaf Area Index (LAI) calculates the total leaf area per unit ground area, taking into account the full 3D structure of the canopy, including leaf angles and distribution throughout the canopy layers.

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Appendix 1. Experts consulted during the review

<u>Dr Allen McIlwee – Department of Climate Change, Energy, Environment and Water</u>
Allen McIllwee is a Senior Scientist with the Spatial Insights Team for the Koala Monitoring and Baseline Program. He has recently been involved in expert elicitation and collation of lists of koala food trees for a variety of modelling purposes.

<u>Bill Faulkner – Environmental Protection Agency</u>
Bill Faulkner is a Senior Technical Policy Officer with the NSW EPA and has had extensive experience on koala matters in northern NSW. This includes 1) involvement with preliminary mapping of habitat for Private Native Forestry, 2) the development of original IFOA protocols, 3) as project manager for the Koala Baseline Mapping Project, and 4) in mapping ARKS.

<u>Dr Brad Law - Forest Science Unit, Department of Primary Industries</u>
Brad Law is a Principal Research Scientist with DPI and has worked as a forest ecologist in NSW forests for more than thirty years, and has researched and published extensively on koalas and koala habitat. His team's work as part of the NRC research program provided detailed information about koala tree use in relation to tree availability, primarily around Kalateenee and Maria River State Forests. Furthermore, the current prescription areas used in the Coastal IFOA are mapped based upon a koala habitat suitability index developed by Brad.

<u>Chris Slade - Forestry Corporation of NSW</u>
Chris Slade is a Senior Ecologist with FCNSW, based in Wauchope. He has more than 20 years of experience as a forest ecologist and has been closely involved with Brad Law's field research in recent years, including hands-on experience with radiotracking koalas and determining trees species use and availability.

<u>John Callaghan</u>
John Callaghan has a long-standing involvement with koala ecology and conservation in north-eastern NSW, both with the Australian Koala Foundation as an Ecologist and Chief Ecologist; as a Koala Conservation Projects Manager for local government and as a consultant ecologist. While running SAT surveys for the AKF, he surveyed all land tenures, but there was a bigger focus on State Forests and National Parks than others. He has particular experience in the Manning, Taree, and Port Stephens LGAs.

<u>John Turbill - Department of Climate Change, Energy, Environment and Water (with input from Mark Fisher, ex. EPA).</u>
John Turbill is a Threatened Species Officer, leading the delivery of koala conservation actions in the NSW Northern Tablelands. He has worked in koala conservation and management on the north coast for over 25 years and has been involved in koala distribution mapping in 3 study areas in the mid-coast LGA, using drone surveys, scat surveys with dogs and tree stem counts.

Peter Higgs – Environment Protection Agency

Peter Higgs has been with the EPA (Coffs Harbour) for eight years and has been involved with koala issues via the Ballina Highway Upgrade in 2018, and through discussions around the current IFOA koala browse tree list.

Dr Rod Kavanagh

Rod Kavanagh has more than 40 years of experience as a Senior wildlife scientist and forest ecologist, with a career spanning roles as a Senior Wildlife Research Scientist with NSW Department of Primary Industries, the Australian Wildlife Conservancy, and as a consultant. He has particular experience in the ecology of folivorous arboreal marsupials and forest owls. He is an Adjunct Associate Professor with Southern Cross University.

Associate Professor Ross Goldingay - Faculty of Science and Engineering, Southern Cross University

Ross Goldingay has been at Southern Cross University, Lismore, since 1996 and is an experienced wildlife ecologist. He has particular expertise in possums and gliders, extending to field studies with koalas around Lismore and in the Richmond Ranges. Much of his research over the last 20 years has been on threatened wildlife species (gliders, koalas, broad-headed snakes, and frogs) and habitat restoration (with glide poles and nest boxes). He has produced >150 peer-reviewed journal papers and book chapters.

Dr Steve Phillips and Kirsten Wallis - Biolink Ecological Consultants

Steve Phillips is a Principal Research Associate with Biolink Ecological Consultants. He has worked in koala research, consultancy and policy for over 40 years. He has played a leading role in the development of numerous Koala Plans of Management, and with the Australian Koala Foundation. He developed and applied the spot assessment technique (SAT) to survey koalas and koala habitat. Steve is an acknowledged authority on the ecology, conservation and management of koalas.

Kirsten Wallis has a background in spatial analysis, including working on Koala Likelihood Modelling for the NSW Government. She is currently working with Steve Phillips at Biolink to collate and analyse SAT data accumulated over several decades.

Appendix 2. Figures of tree species co-occurrence

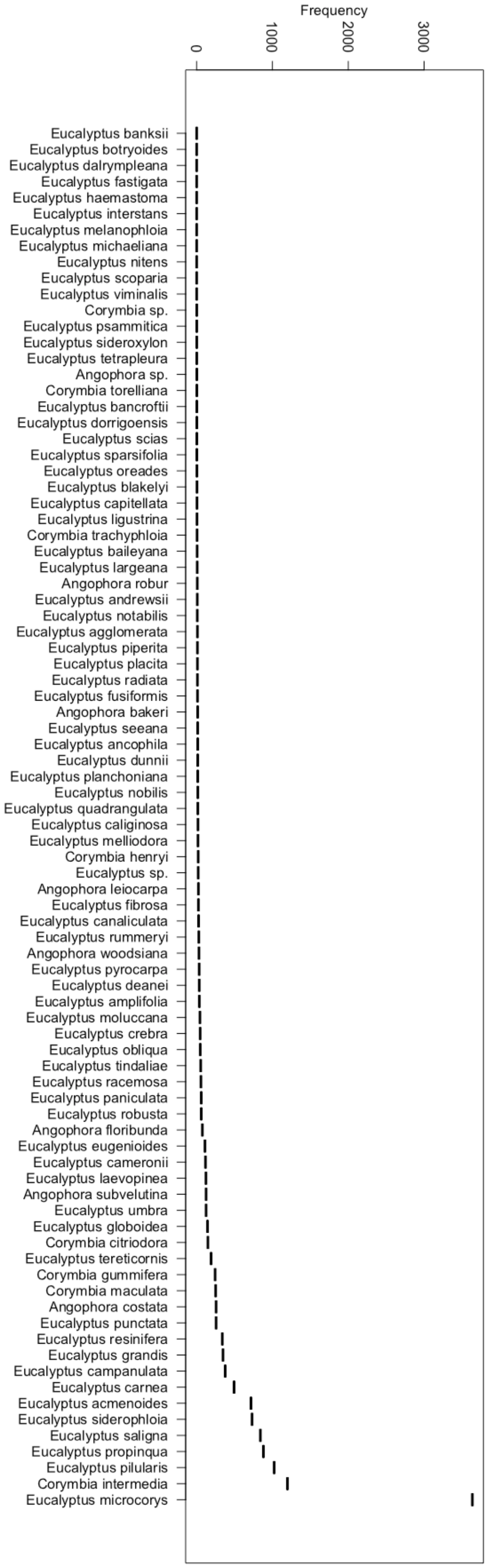
The following figures are provided to guide thinking about the potential environmental impacts of altering the koala browse list. If new species are added to the list, then they may be retained at the expense of other co-occurring species; if the species do not co-occur or co-occur only very rarely, then this risk is diminished.

For example, *E. microcorys* (tallowwood) is present alongside *E. propinqua* (small-fruited grey gum) at half of all plots occupied by *E. propinqua* (small-fruited grey gum). This suggests that elevating *E. propinqua* (small-fruited grey gum) to a status matching *E. microcorys* (tallowwood) could lead to a net decreased retention of *E. microcorys* (tallowwood). The impact of adding *E. resinifera* (red mahogany) to the list carries less risk – the browse tree that co-occurs most often with it is *E. microcorys* (tallowwood) (27% of sites). Because *E. microcorys* (tallowwood) is a primary browse tree, it is partially isolated from changes to the secondary browse tree list (not entirely as secondary trees are allowed to replace up to half of retained primary browse trees). Other browse or potential browse trees co-occuring with *E. resinifera* (red mahogany) are *E. siderophloia* (ironbark) (14% of sites, but we do not suggest it be added to the list), *E. robusta* (swamp mahogany) (10% of sites), *E. propinqua* (small-fruited grey gum) (9% but we suggest it be prioritised above other secondary browse trees), *E. punctata* (grey gum) (7%, ditto), *C. maculata* (spotted gum) (7%, not suggested to be added) and *E. saligna* (Sydney blue gum) and *E. tereticornis* (forest red gum) (both 5%).

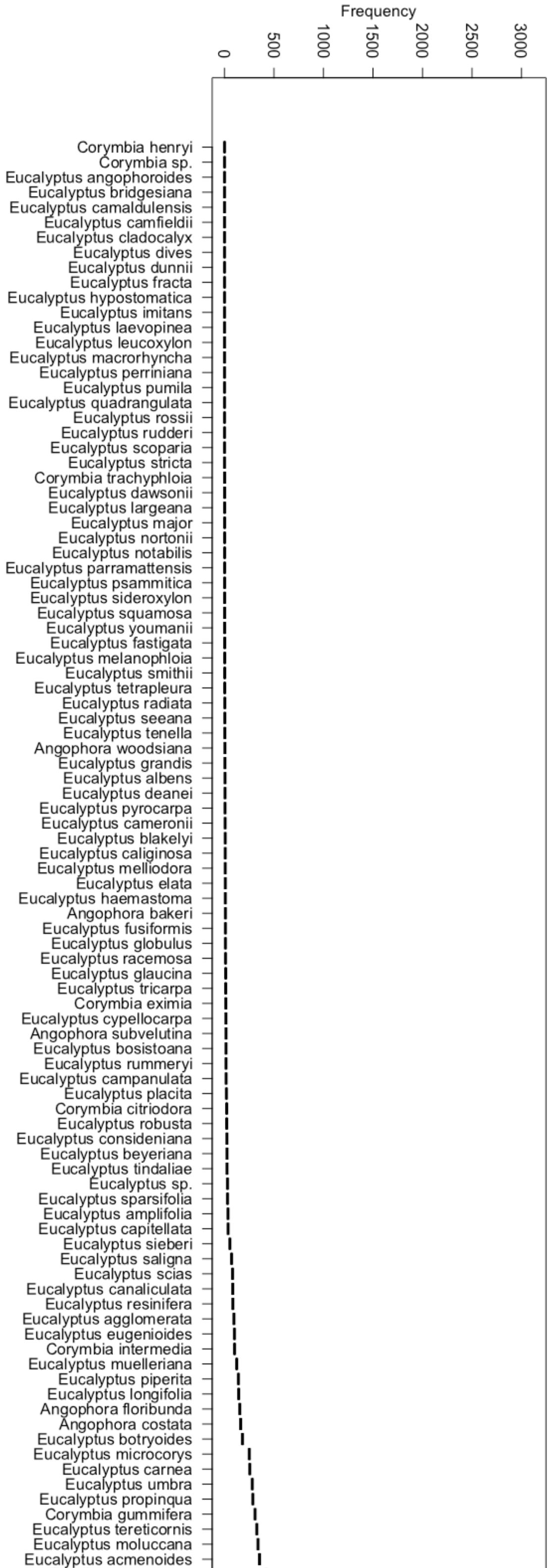
The figures are drawn from a dataset of 205,084 vegetation plots from throughout Australia. Each figure indicates the number of plots in which the focal species was found, and the number of those sites in which each of the remaining species were also found. For example, *C. maculata* (spotted gum) was found in 3,122 HAVPlots, and the most commonly co-occurring species was *E. globoidea* (white stringybark) which occurred at 585 (19% of those sites). It should be noted that the vegetation included in HAVPlots might not be representative of that across State Forests and so to better assess the risk associated with alterations to the browse tree list, this exercise should be replicated with State Forests inventory data.

These figures have been generated from the CSIRO Harmonised Australian Vegetation Plot dataset (HAVPlot). Citation: Mokany, Karel ; McCarthy, James ; Falster, Daniel ; Gallagher, Rachael ; Harwood, Tom ; Kooyman, Robert ; Westoby, Mark (2022): Harmonised Australian Vegetation Plot dataset (HAVPlot). v2. Commonwealth Scientific and Industrial Research Organisation (CSIRO).dataset.32047; 3; 17egz/6u92 . Thanks to Laura Williams (Hawkesbury Institute for the Environment, Western Sydney University) for help with summarising these data.

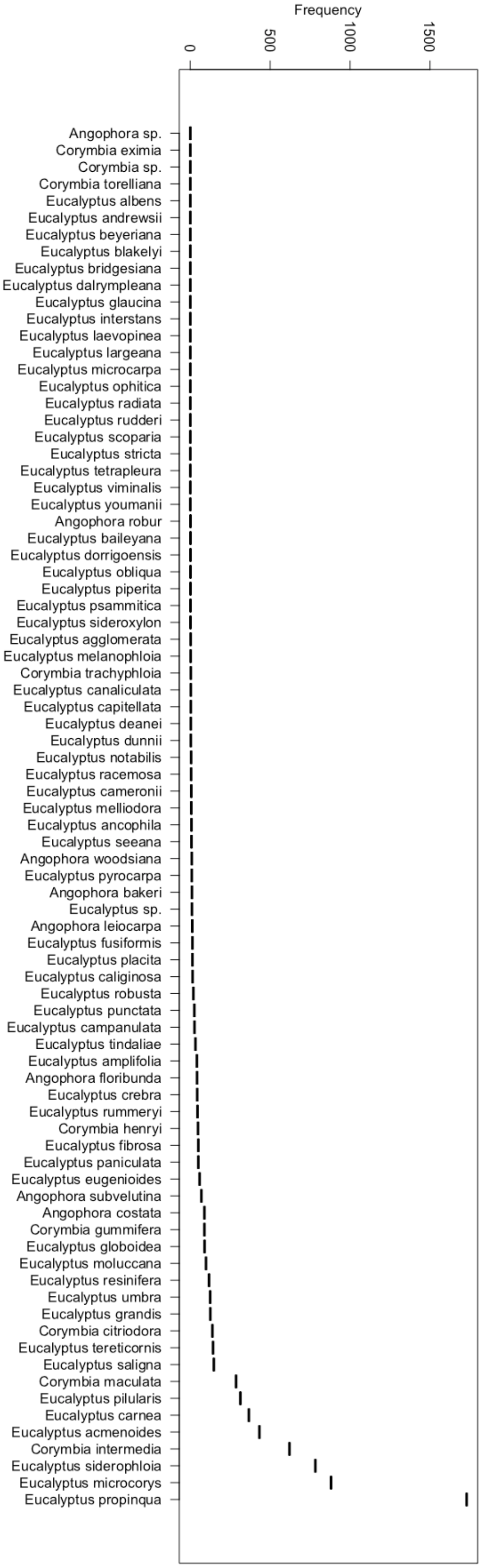
Tree species co-occurrence with *E. microcorys* (tallowwood)*:*



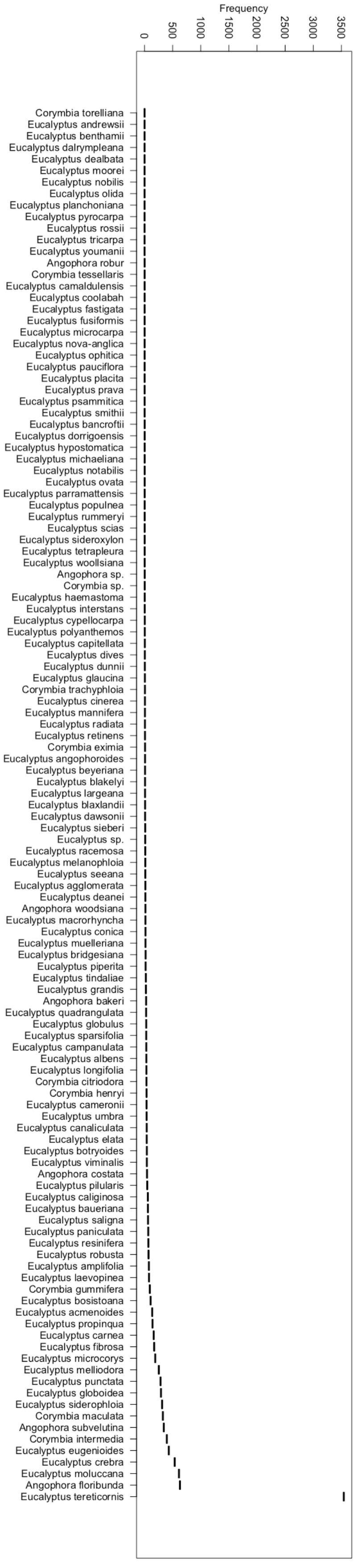
Tree species co-occurrence with *C. maculata (spotted gum):*



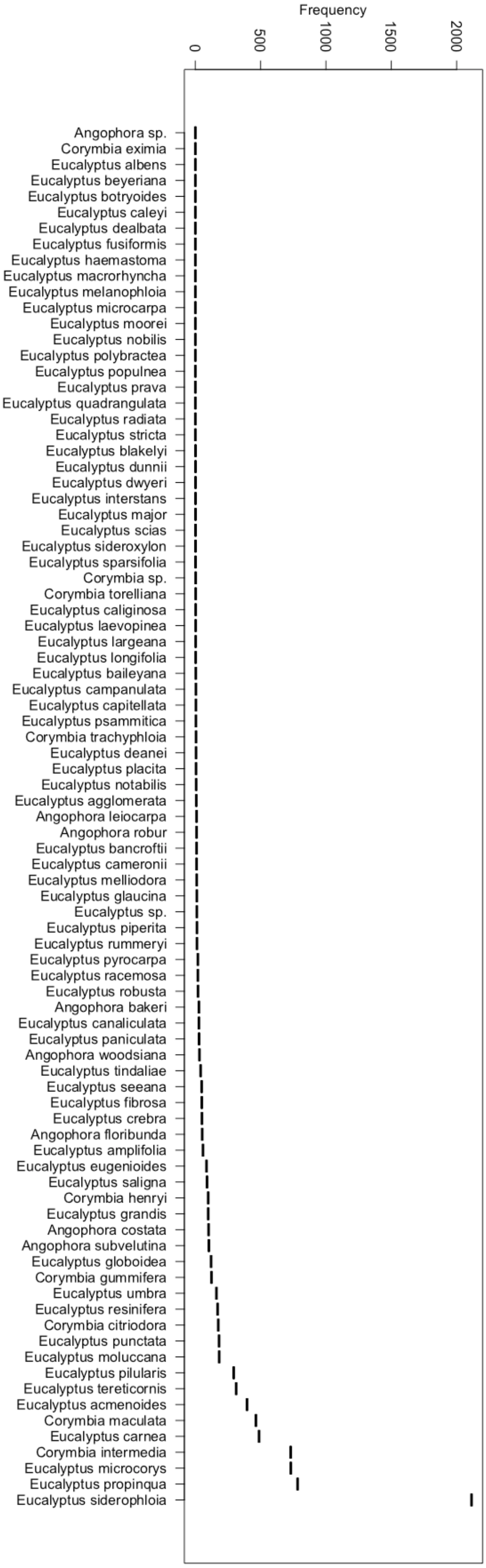
Tree species co-occurrence with *E. propinqua* (small-fruited grey gum)*:*



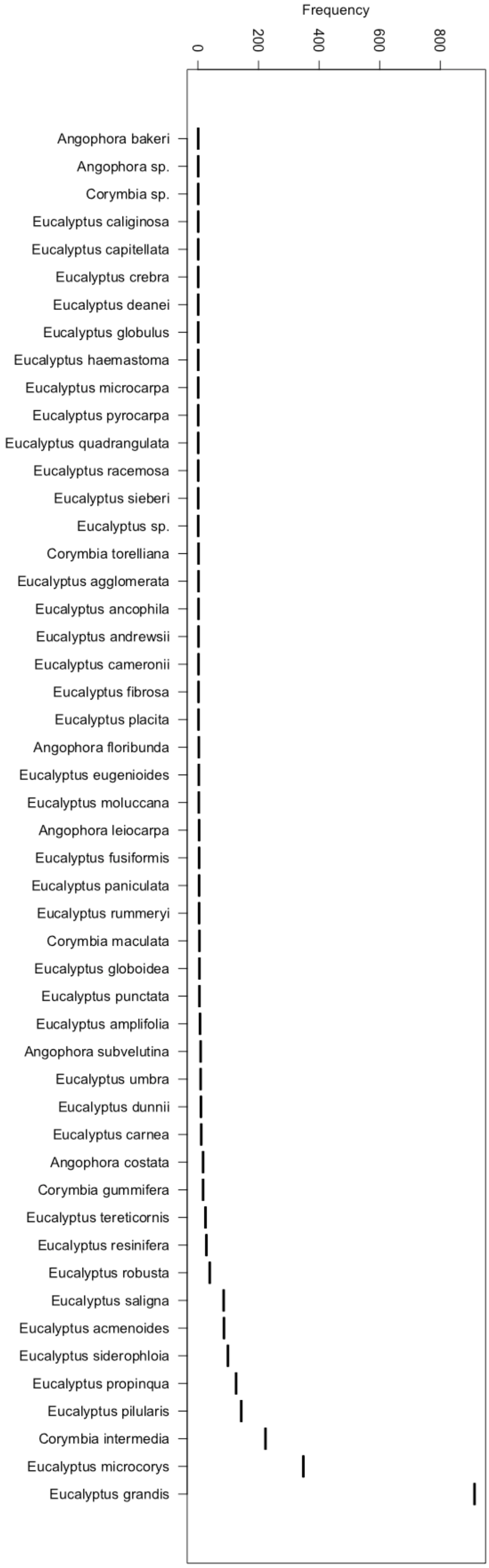
Tree species co-occurrence with *E. tereticornis* (forest red gum)*:*



Tree species co-occurrence with *E. siderophloia* (northern grey ironbark):



Tree species co-occurrence with *E. grandis* (flooded gum):



Tree species co-occurrence with *E. resinifera* (red mahogany):