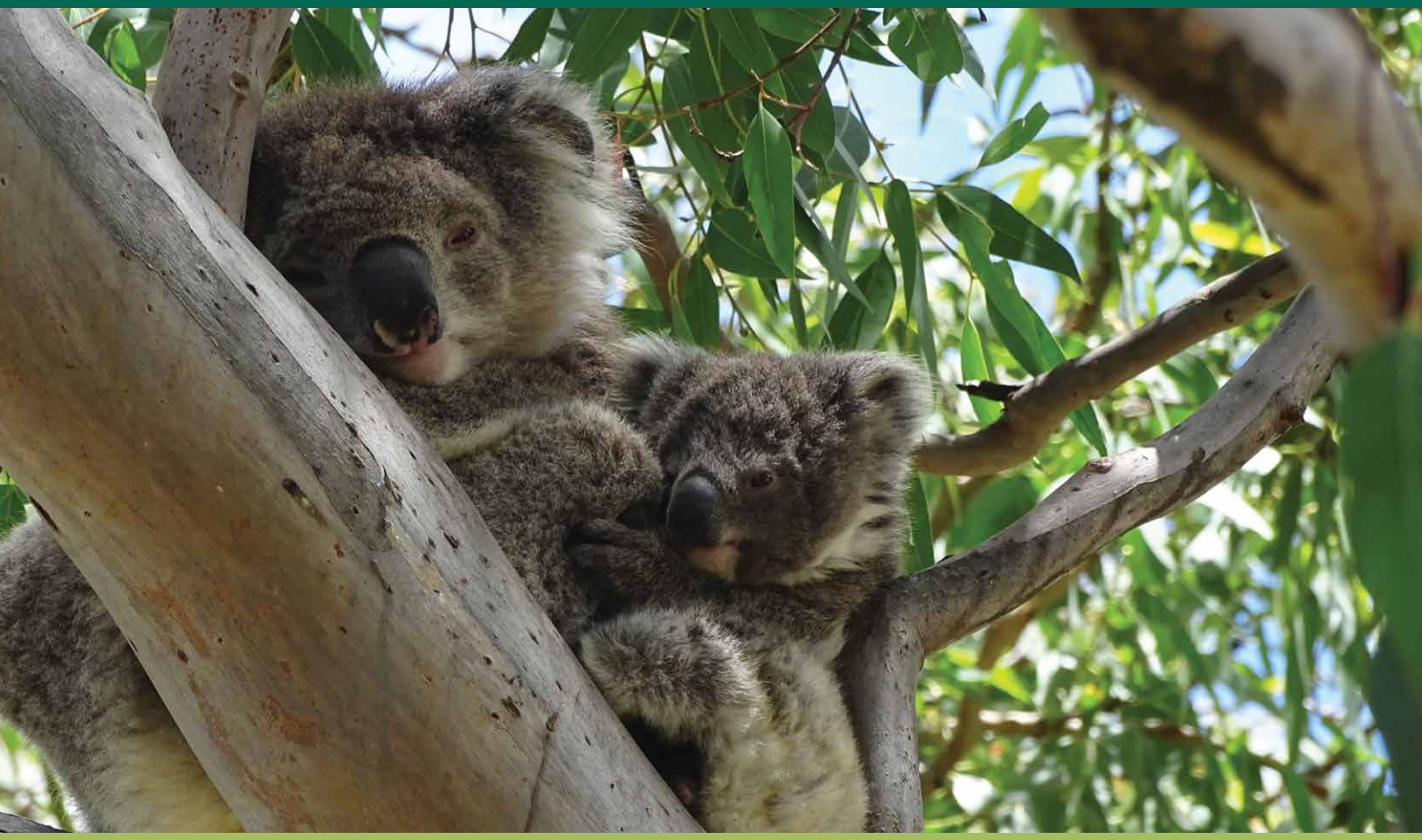
Threatened Species Recovery Hub

National Environmental Science Programme



Mapping koala habitat for greater Queensland report

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The University Of Queensland AUSTRALIA

Queensland Government

Australian Government Geoscience Australia

NSW Government Planning, Industry & Environment

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Cover image: Koala. Image: Annika, Unsplash

Contents

Summary

This dataset was developed to support a nationally harmonised habitat map for the listed Koala. Maps of koala habitat in Queensland were developed using a protocol adapted from that used to map koala habitat in SEQ (DES 2020a). Briefly, regional ecosystems were ranked according to their predicted utility to koalas and overlaid with predictions of the environmental suitability of the landscape for koalas to generate a predicted ranking of utility of habitat for koalas in each planning unit.

Usage

This dataset was developed to inform broad-scale conservation planning associated with the National Koala Recovery plan. The data will be used to inform an updated model of koala distribution and used in spatial query tools that support environmental impact assessments, recovery planning and other spatial analysis in the Commonwealth Department of Agriculture, Water and the Environment (DAWE).

The spatial resolution is 1km (100ha) and it is not intended for identifying habitat at a fine scale. The dataset has not been ground-truthed. Some areas identified as potential habitat may be too degraded or contain insufficient resources for koalas to occupy. Koalas may be present outside the areas identified as potential habitat. For uses within the South-East Queensland planning area we recommend using alternate mapping (DES 2020a).

Runge CA, Rhodes JR, Cubillos-Lopez DS. 2021. Queensland koala habitat mapping. Version 2.0. NESP Threatened Species Recovery Hub Project 4.4.12 report. The University of Queensland, Brisbane. https://doi.org/10.5281/zenodo.4305179

Spatial extent

The dataset spans koala habitat across Queensland. Study region boundaries were drawn by selecting IBRA7 bioregions within Queensland (Department of the Environment 2012) that intersected Commonwealth koala distribution maps (DAWE 2019). Cape York and Gulf bioregions were excluded, and the eastern portions of Mitchell Grass Downs were included as per (Adams-Hosking et al. 2016). The study region was projected to GDA94 Australian Albers projection (EPSG:3577).

Acronyms

DES	Department of Environment and Science (Queensland)
DAWE	Department of Agriculture, Water and the Environment (Commonwealth)
DNRME	Department of Natural Resources, Mines and Energy (Queensland)
DotE	Department of the Environment (Commonwealth, former)
DPIE	Department of Planning, Industry and Environment (NSW)
OEH	Office of Environment and Heritage (NSW)

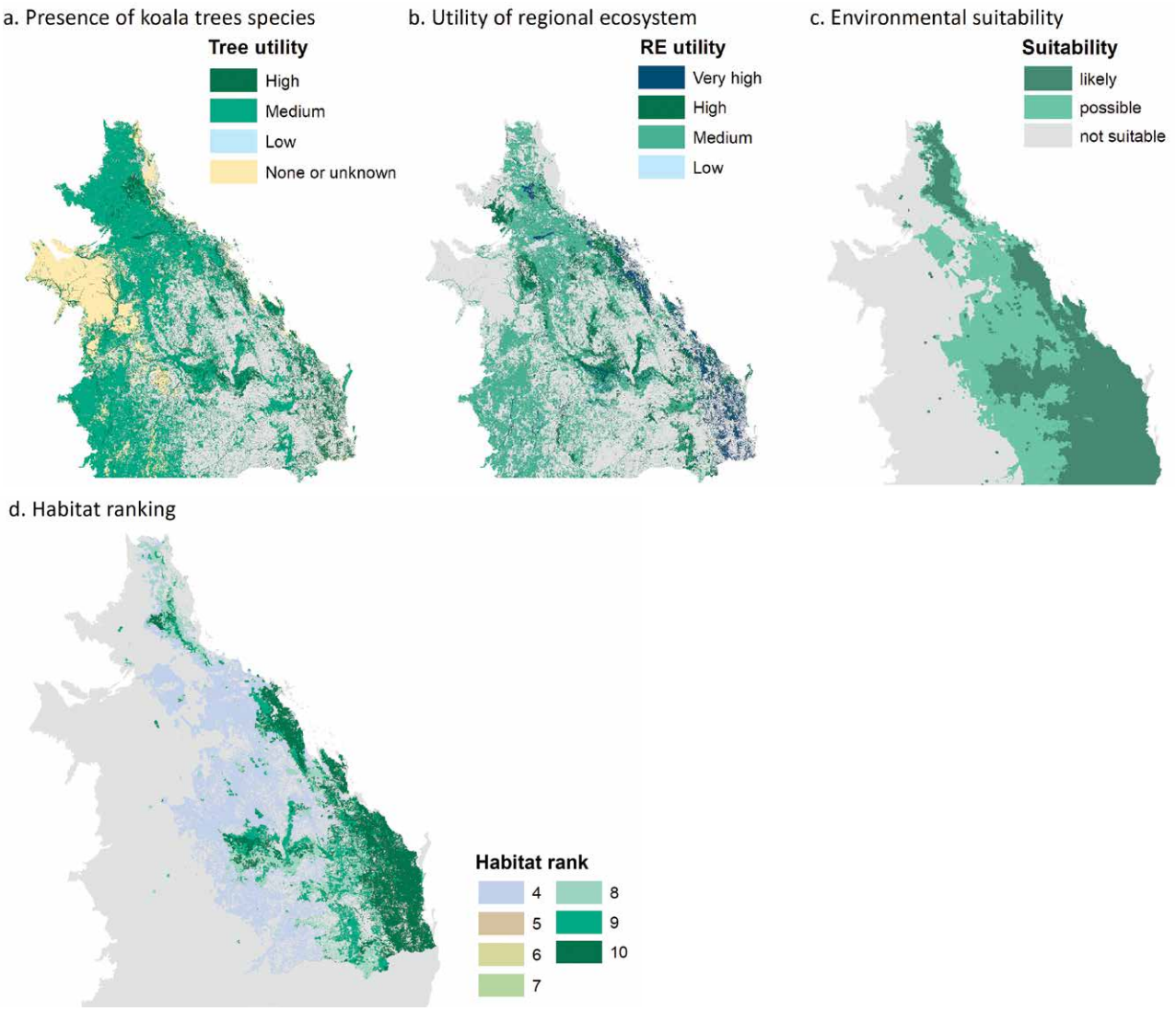

Figure 1. Habitat mapping for greater Queensland a. Presence of tree species used by koalas, b. Ranking of suitability of regional ecosystem for koalas, based on presence of tree species utilised by koalas and prevalence of recorded use of ecosystem by koalas, c. Ranked environmental suitability of landscape for koalas and d. Predicted habitat for koalas, which combines the regional ecosystem ranking (b) with modelled predictions of the environmental suitability (c) to rank the habitat suitability of each 100ha cell for koalas.

Methodology

Step 1. Mapping the presence of koala tree species

First, lists of tree species used by koalas were compiled from published literature. As koala tree use differs across their range, lists were developed for each bioregion. Tree species were ranked according to the reliability of evidence for their use by koalas (Table 1). Detailed methodology and lists of tree ranking can be found in Appendix S1. Regional ecosystems (REs) containing or potentially containing trees used by koalas were then identified from the description of each of the REs (Queensland Herbarium 2019; Figure 1b). We limited our analysis to regional ecosystems within IBRA7 bioregions (DotE 2012) that intersected Commonwealth koala distribution maps (DAWE 2019). Cape York and Gulf bioregions were excluded, and the eastern portions of Mitchell Grass Downs were included as per (Adams-Hosking et al. 2016).

The tree utility was then linked to spatial mapping of remnant regional ecosystems (DNRME 2020) using the predominant RE in each polygon (RE1). As we were interested in remaining koala habitat we linked to the remnant RE shapefile. Mapping of pre-clearing regional ecosystems also exists, and this could be used as an alternate where the purpose of mapping is to identify the proportion of each regional ecosystem that has been lost, or areas where restoration might recover high-quality habitats for koalas.

Table 1. Tree species utility classes used to help rank the regional ecosystems (source:(Department of Environment and Science 2020)).

Tree species utility class	Description
Higher	Species referred to in a variety of reports and literature, the majority of which were definitive studies, described as being an important utility species for koala.
Medium	Species referred to in some reports and literature, can be secondary or anecdotal reference to species used by koalas e.g. species included in a factsheet.
Lower	Species not referred to in any literature or considered a trace food species for koalas from a definitive study, and/or eucalypt.
None or unknown	Species not referred to in any literature, not eucalypt, melaleuca or lophostemon.

Step 2. Ranking of regional ecosystem suitability

The suitability of regional ecosystems to koalas (Figure 1b) was ranked based on the presence of tree species used by koalas and the prevalence of records of koala use of each ecosystem. The RE suitability ranking matrix in

Table 2 was applied to determine the suitability of each regional ecosystem to koalas. The proportion of polygons of each regional ecosystem where koalas have been recorded since 1970 (1 January 1970 to 19 May 2020) was estimated from koala occurrence records drawn from WildNet (DES 2020b). Records with spatial accuracy greater than 1000m were excluded as were records with > 12 months uncertainty around the sighting date. Records falling outside Queensland land borders, museum or voucher records, and duplicates were excluded. Records falling within the south-east Queensland planning area were excluded, leaving 2387 records of koala occurrence. Records were buffered to 1km consistent with the spatial accuracy of the records.

Table 2. Preliminary regional ecosystem (RE) suitability ranking.

	Regional ecosystem suitability			
	Very high	High	Medium	Non-habitat
Koala tree species present in RE	Yes	Yes	Yes	Yes
Utility of tree species to koalas*	High	Medium	High or medium	
Records of koalas in RE since 1970	Yes	Yes	Yes	No
Percent of RE polygons contain koala records	>1%	>1%	Any	

*Methods used to rank utility of tree species for koalas can be found in Appendix S1: Classification of tree species utility to koalas.

Step 3. Ranking and mapping habitat utility of each planning unit for koalas

The habitat utility of the study region (Figure 1c) was ranked using the habitat ranking matrix in Table 3. Habitat ranked 4 to 7 was assigned as 'possible' habitat and habitat ranked as 8, 9 or 10 was assigned as 'likely' koala habitat.

The study region was divided into 100 ha hexagonal planning units (approximately 1 km in diameter) and the proportion of habitat of each ranking in each planning unit was calculated from the habitat ranking matrix. Firstly, each planning unit was assigned an environmental suitability ranking. Next planning units that overlapped 1km buffered koala occurrences described in step 2 were assigned as 'record since 1970'. Finally, the area of habitat in each planning unit was calculated from the area of regional ecosystems ranked very high, high or medium intersecting each planning unit. A planning unit was assigned the rank of the highest ranked ecosystem in that planning unit.

Table 3. Habitat ranking matrix. Habitat ranked as 8, 9 or 10 was classified as likely habitat (green), and habitat ranked as 4 to 7 was classified as possible habitat (pale blue).

			Regional ecosystem suitability				
			Very high	High	Medium	Low or Unknown	Non-habitat
Environmental suitability rank	High	Record since 1970	10	9	8	0	0
		No record since 1970	10	9	8	0	0
	Medium	Record since 1970	7	6	5	0	0
		No record since 1970	4	4	4	0	0
	Low	Record since 1970	0	0	0	0	0
		No record since 1970	0	0	0	0	0

Environmental suitability ranking

The environmental suitability ranking of each planning unit for koalas was aggregated from three datasets of koala bioclimatic distribution. These are: **1) SNES 2020:** an unpublished koala distribution model provided by DAWE (*Chris Meakin personal communication July 7 2020*); **2) Complex KHSM:** a koala distribution model developed by the NSW government (DPIE 2019) for the entire koala range and described in ('complex KHSM'), and **3) Briscoe niche:** A set of 3 correlative and 3 biophysical models of koala climate tolerance (Briscoe et al. 2016). The datasets differ in their predictions of where the boundary of environmental suitability for koala lies, particularly in western and northern regions where there are few recorded koala observations. For this reason, we applied a precautionary approach and assigned a value of suitable if any of the three datasets predicted an area to be suitable for koalas (Table 4).

Table 4. Environmental suitability rankings.

Environmental Suitability Ranking	
High	SNES 2020 polygons classed as 'known or likely to occur' intersect with planning unit OR the logistical value of the complex KHSM at the planning unit centroid falls within 0.444-1 OR the planning unit overlaps the majority (> 3) of Briscoe niche models thresholded such that 95% of recent records fall within the niche.
Medium	SNES 2020 polygons classed as 'may occur' intersect with planning unit OR the logistical value of the complex KHSM at the planning unit centroid falls within 0.3925-0.444 OR the planning unit overlaps the majority (> 3) of Briscoe niche models thresholded such that 99% of recent records fall within the niche.
Low	Areas outside high or medium environmental suitability.

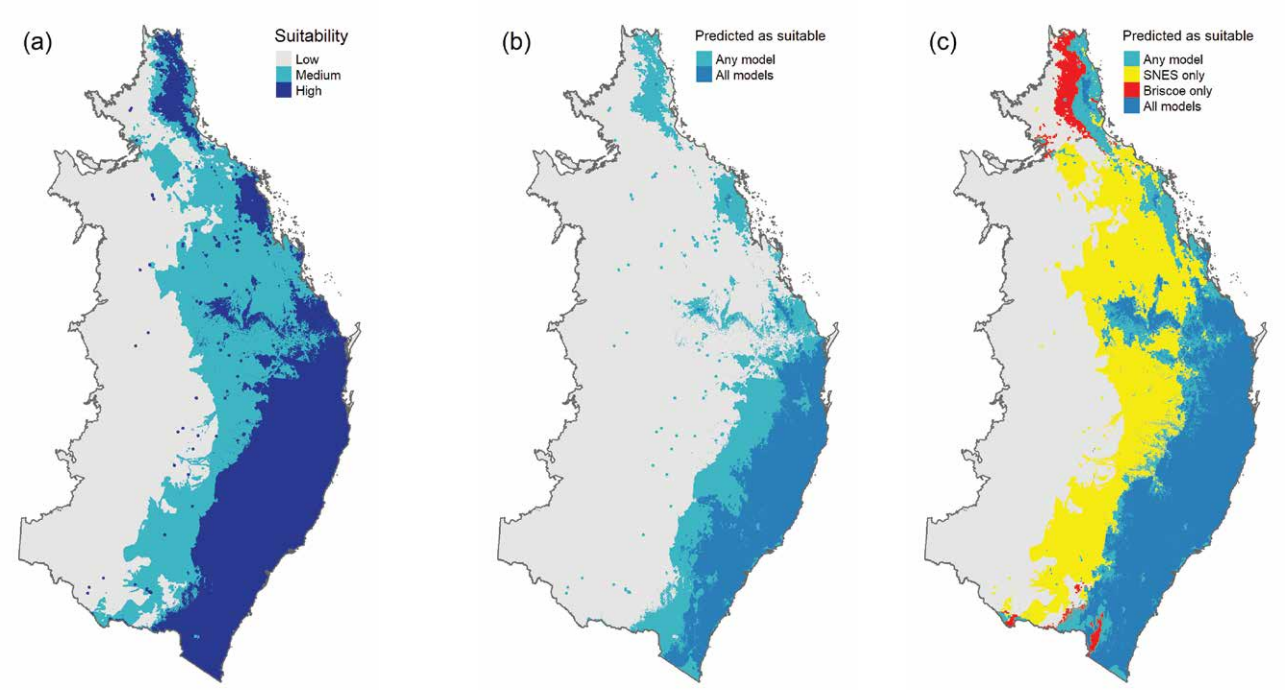

Figure 2. (a) Environmental suitability ranking for koalas, (b) contribution of models to 'high' environmental suitability ranking, with areas predicted as highly suitable under all three models shown in dark blue, and areas predicted as highly suitable under any of the three models shown in teal, and (c) contribution of models to 'medium' environmental suitability ranking, with areas predicted as medium suitability under all three models shown in dark blue, areas predicted as medium suitability under any of the three models shown in teal, areas predicted as suitable only under the SNES 2020 model shown in yellow, and areas predicted as medium suitability only under the Briscoe models shown in red.

Details of koala climatic distribution models

In the SNES 2020 koala distribution map, the category 'Species known to occur' represents post-2000 koala occurrence records buffered to 1km. Categories 'Species likely to occur' and 'Species may occur' were determined by thresholding a Maxent model that used spatially thinned koala observations and a set of climatic and biophysical variables at values representing the fixed cumulative value 10 and maximum training sensitivity plus specificity respectively. Planning units overlapping both 'likely to occur' and 'may occur' polygons were designated 'likely to occur' for the purposes of habitat ranking.

Two thresholds were applied to the complex KHSM. Firstly, a planning unit was assigned as high environmental suitability if the value underlying the centroid of each planning unit was > 0.444 (equal sensitivity and specificity value). Secondly a planning unit was assigned as medium environmental suitability habitat if the value underlying the centroid of each planning unit was > 0.3925 (max kappa value).

The Briscoe niche models map climatic suitability for koala at approximately 5km resolution (0.05 degree) under a set of six models: three correlative species distribution models generated using climatic variables, and three bioenergetics models. These six models had then been projected onto current climate conditions to generate 6 predictions of current climate suitability for koala.

Next, each of these 6 maps was thresholded to generate binomial maps (0 = not climatically suitable, 1 = climatically suitable). Thresholds were chosen to represent different tolerances of uncertainty in the mapping process. These were calculated from the value within which 90, 95 and 99 % of koala records from 01 Jan 2000 onwards fall, with 90% representing the core climate niche, 95% representing the mid climate niche and 99% representing the peripheral climate niche and a higher level of within-model uncertainty. Koala records were first spatially thinned by random sampling a single record from within each 1km planning unit.

Finally, we summed across the binomial maps in the given time period, with equal weighting given to all models. The resulting values represent the number of climate scenarios where that planning unit is predicted to be climatically suitable for koala. Values range from 0-6 for current climate and were calculated for each threshold (90, 95 or 99% of koala records). A value of 4 or greater represents an area that is predicted as suitable across the majority of models

Data processing

Data processing and analysis was conducted using ArcGIS (ESRI 2020) and R (R Core Team 2020) using packages 'tidyverse' (Wickham et al. 2019), 'raster' (Hijmans 2020), and 'sf' (Pebesma 2018). Code associated with the project can be found at https://doi.org/10.5281/zenodo.4305356.

Datasets

The following datasets can be found at https://doi.org/10.5281/zenodo.4305179

- Queensland koala habitat map (GeoPackage, Qld_habitat_rank_100ha_v2.gpkg)
- Queensland regional ecosystem suitability for koalas (shapefile, Qld_RE_utility_v2.shp)
- Dataset supporting regional ecosystem suitability ranking (comma separated table, REDD_QldnoSEQ_summary_for_RE_ranking_v2.csv)
- Modelled environmental suitability for koalas (shapefile, env_suitable.shp)
- List of tree species utilised by koalas in Queensland, by biome (comma separated table, Koala_tree_list_TableA2.csv)
- Ranking of regional ecosystems used by koalas (comma separated table, RE_sp_tree_suitability_appendix_table1.csv)

List of appendices

Appendix S1: Classification of tree species utility to koalas

Appendix S2: External review of Queensland habitat mapping

Acknowledgements

We would like to acknowledge the Traditional Owners of the land on which this research was conducted. We pay our respects to their Ancestors and their descendants, who continue cultural and spiritual connections to Country. We recognise their valuable contributions to Australian and global society.

We thank Harriet Preece and Alistair Melzer for their generous advice and help in developing this dataset.

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Appendix S1: Classification of tree species utility to koalas

S1.1 Methods

We created a summary list of the tree species that have been reported to be used by koalas. We used the classification of tree species utility described in *Spatial modelling for koalas in South East Queensland* (DES 2020). Table S1 lists the reference sources used to generate the list of koala tree species.

We updated the species list from DES (2020) using the following scientific papers and two reports from New South Wales (Table S 1. Documents used to update tree species used by koalas in Queensland and New South Wales.). Many tree species changed their original classification (DES 2020) to 'Medium' according to the categorisation set out in Table 1. The list of tree species and their ranking can be found in the datasets associated with this report.

Table S 1. Documents used to update tree species used by koalas in Queensland and New South Wales.

Title	Source	Type
Ranking and mapping koala habitat quality for conservation planning on the basis of indirect evidence of tree-species use: a case study of Noosa Shire, south-eastern Queensland.	(Callaghan et al. 2011)	Scientific paper
Ecology and movement of urban koalas adjacent to linear infrastructure in coastal south-east Queensland.	Oliveira et al. (2014)	Scientific paper
Fine-scale changes in spatial habitat use by a low-density koala population in an isolated periurban forest remnant.	Lollback et al. (2018)	Scientific paper
Low-density koala (*Phascolarctos cinereus*) populations in the mulgalands of south-west Queensland. IV. Abundance and conservation status.	Sullivan et al. (2004)	Scientific paper
Scattered paddock trees and roadside vegetation can provide important habitat for koalas (*Phascolarctos cinereus*) in an agricultural landscape.	Barth (2020)	Scientific paper
The dietary preferences of koalas, *Phascolarctos cinereus*, in southwest Queensland.	Wu et al. (2012)	Scientific paper
The habitat and diet of koalas (*Phascolarctos cinereus*) in Queensland	Melzer et al. (2014)	Scientific paper
Koala Habitat Information Base Technical Guide	DPIE (2019)	Government report
A review of koala tree use across New South Wales	OEH (2018)	Government report

S1.2 Summary of tree species utility in biomes and regional ecosystems

We identified the important tree species for koalas in each Regional Ecosystem (RE) by extracting tree species names from the vegetation description of each regional ecosystem (Queensland Herbarium 2019). Most of the species are classified as none or unknown utility and very few species have a high classification (Figure S 1). South East Queensland is the biome with the highest number of tree species used by koalas, whereas Mitchell Grass Downs has the lowest (Figure S 1). New England Tableland has the larger number of species classified as medium utility which may reflect a lack of published research in this biome (Figure S 1. Number of tree species per biome for each species utility).

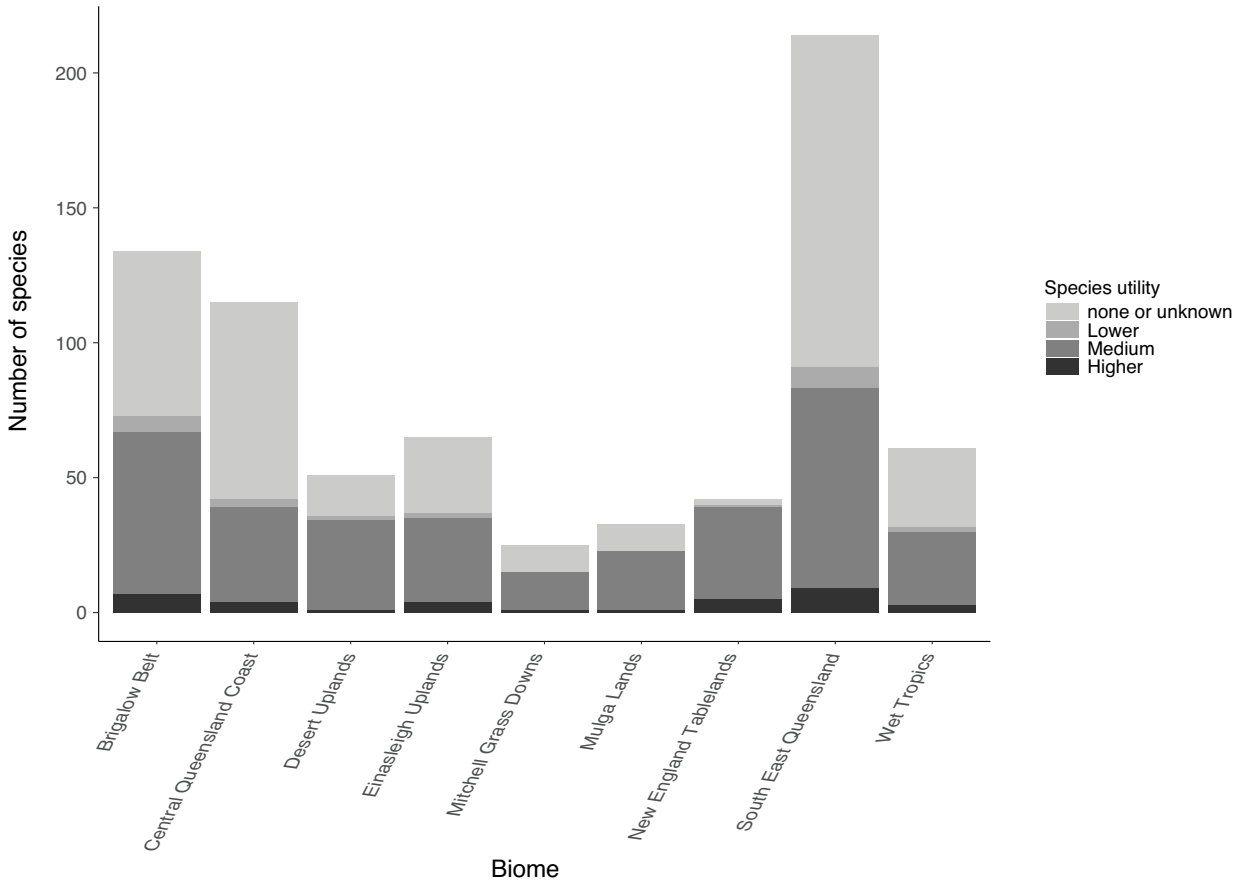


Figure S 1. Number of tree species per biome for each species utility.

Large areas of Queensland contains tree species utilised by koalas (Figure S 2A), although koalas are not recorded in all these areas. In some regional ecosystems, more than one tree species is listed in the regional ecosystem description (Queensland Herbarium 2019) (Figure S 2B-D). Tree species in the higher utility class are mainly located in South East Queensland, Brigalow Belt and Central Queensland Coast (Figure S 2B). Mitchell Grass Downs and the Wet Tropics are the regions least likely to contain tree species utilised by koalas ('none or unknown' species category Figure S 2A).

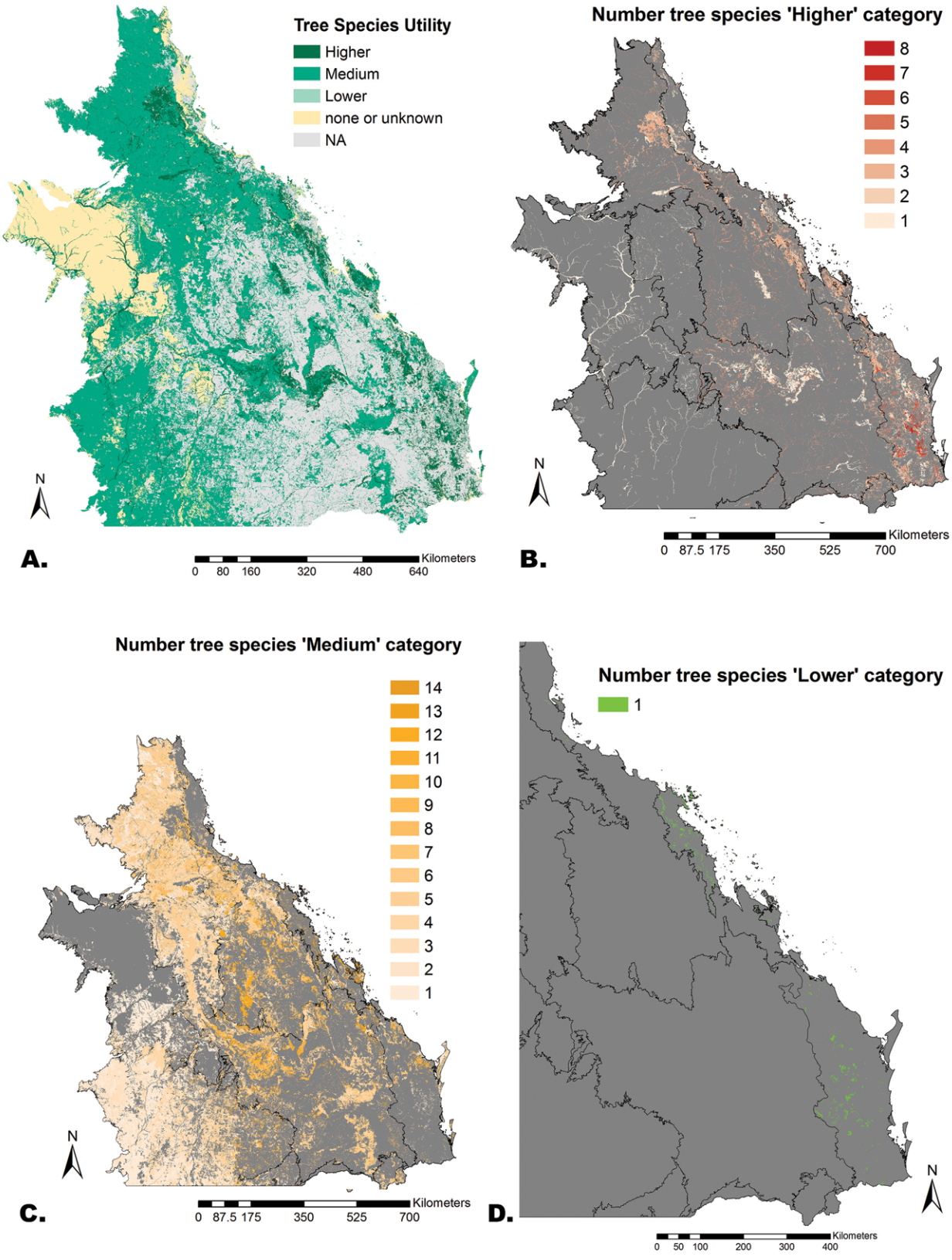
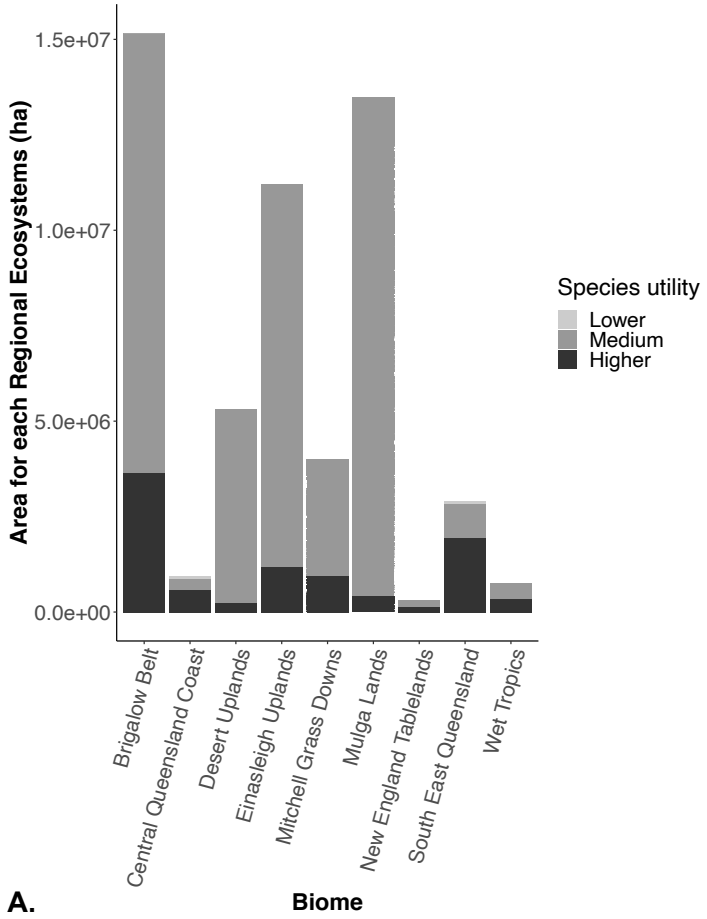


Figure S 2. A. Map of the tree species utility per biome. NA on the legend represents regional ecosystems named as: 'Non-rem', 'Estuary', 'Canal', 'Ocean', 'Sand', 'Shallow', and 'Water'. B. Count of species in higher category. C. Count of tree species in medium category. D. Count of tree species in lower category.



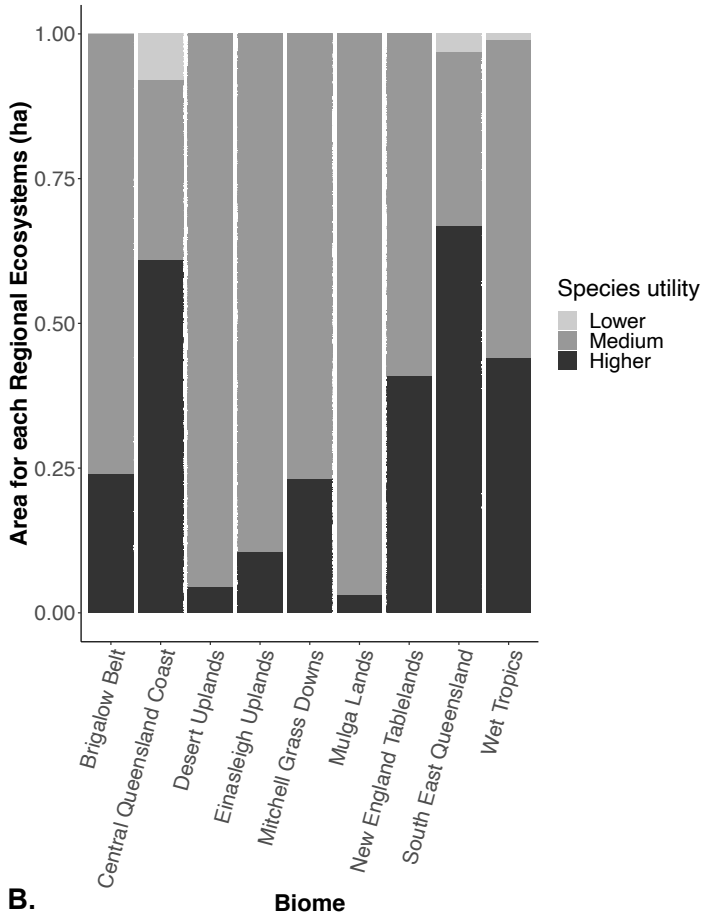


Figure S 3.Area of the regional ecosystems in each biome containing tree species utilised by koala, by tree species utility class.

Appendix S2: External review of Queensland habitat mapping

Prior to publication, a review of these methods was requested from the team that developed the SEQ koala mapping at Queensland Department of Energy and Science. This review is included below, with annotations noting where changes have been made to the methods following this review.

Request

Review the NESP draft koala habitat mapping for Queensland.

Background

NESP have been working with the Commonwealth on broad-scale planning in association with the national koala recovery plan, to determine nationally important areas where koala might persist for the next 100 years.

Review

Summary

- NESP have produced mapping that ranks koala habitat suitability at a broad scale (100ha) across the whole of Queensland.
- Due to its coarse scale, NESP mapping is unlikely to be suitable for inclusion in statutory mapping such as Essential Habitat under the Vegetation Management Act.
- Overall the NESP mapping looks good and encompasses the majority, but not all, core and non-core habitat delineated by DES in the SEQ Bioregion which is the only region with a Biodiversity Assessment Team (BAT) Habitat Suitability Model (HSM) where a comparison is possible. Additional detailed analyses would be required to quantify the differences between the NESP and DES models.
- NESP has adopted the same approach developed by DES for SEQ koalas (DES 2020). The similarities include:
  - Using separate Maxent and RE suitability models and combining them using a decision matrix to rank habitat
  - Using koala presence records to confirm known habitat. Note that NESP used only recent records ie post 2000.
- Difference with the DES SEQ model include:
  - NESP used only recent koala sighting records (post 2000) in both the RE model (to designate suitability) and in the matrix (to confirm known habitat).

NOTE: Methods have been adjusted following this review to use koala sightings post 1970 in the RE model and records from 2000 onwards in the matrix

  - NESP used only RE1 to ascribe regional ecosystem suitability whereas DES used all RE components (RE1-RE5) of heterogeneous polygons.
  - NESP Maxent models were obtained from external departments rather than in-house which has limited the ability to review the on-ground suitability and refinement. Minimal documentation also makes it difficult to assess.
- It is unclear how the NESP will be used and how it fits in to any existing mapping or policy at either the state or national level?

NOTE: The report has been edited following this review to reflect the use of this dataset. The data will be used to inform an updated model of koala distribution and used in spatial query tools that support environmental impact assessments, recovery planning and other spatial analysis in DAWE.

- DES plans to extend our model to include the northern part of the Southeast Queensland bioregion and then to the full extent of koala habitat within Queensland. However this is dependant on available time and resources.

Suggestions

1. Consider developing the RE model using all koala records (not limited to post 2000) to get a better representation of koala habitat suitability.
   a. Suggest using a date cut-off of post 1975 for compatibility with DES although the post 1970 date already pre-processed would also be suitable.
   b. Note that NESP can still use the recent records (post 2000) for the matrix component and compatibility with the Commonwealth.
2. Address the heterogeneous regional ecosystem polygon issue by using all REs (RE1-RE5) rather than only RE1.
3. Enable koala experts to review the RE suitability ranking and adjust accordingly. It is acknowledged that this will take time to assess all koala REs across Qld.

4. Look at whether it might be possible to refine the Maxent models using bioregion specific variables. It is noted that this would take a considerable amount of time given the large number of bioregions and bioclimatic conditions across the state.
5. The majority of the other issues relate to technical or refinement matters and are unlikely to greatly alter the final model although some sensitivity analyses would be good to verify this. (See detailed feedback for more info).

Detailed Feedback

General

- Koala records post 2000 – NESP limiting the RE model to only recent records (post 2000) may not be the best representation of habitat suitability given the decline in koala numbers since 2000 would have severely reduced the number of records available for developing the model. Using recent koala records may be appropriate for the matrix component of the modelling, as it would be compatible with the date threshold used by the commonwealth.
  - Note, DES used older sighting records (post 1975) in both the matrix and as an aid to inform the koala experts who decided the RE suitability. Modelling habitat suitability using older records allows us to identify where habitat was and suitability for rehabilitation. Koala presence can be confirmed using recent records as a component of the matrix or as a separate overlay as new records are obtained.
- Would have been good to see the results for SEQ planning region for comparison purposes. Not sure whether this has been masked-out and why? Ie has the modelling been done for SEQ and masked and the underlying data is available?
- It would be possible to undertake a more detailed analysis by comparing NESP with BAT SEQ planning and bioregion models.
- It could be useful to see both pre-clearing and remnant versions of the model or to investigate the differences.
- It would be useful to receive a copy of the koala records for review and comparison with the DES SEQ models. The source of Qld koala records was WildNet. (Note documentation says BioNet).
- It would be helpful to see the national koala distribution model used for the "environmental suitability rank" and sourced from Species of National Environmental Significance (SNES), Department of Agriculture, Water and the Environment (DAWE).
- For transparency, it would be good to retain the full suite of attributes in the model rather than the dissolved version with only 'Habitat rank' and 'Environmental suitability'.

Technical

- Heterogeneous regional ecosystem polygons – NESP has used only RE1 and avoided the technical complexity of processing mixed polygons. The disadvantage is that regional ecosystems important to koalas may have been excluded if they were in any of the other four components (ie RE2/RE3/RE4/RE5) even if their combined area was a major portion of the polygon.
  - The DES approach would assign an overall rank based on the combined area of the individual components. For example, if a heterogeneous polygon was non-habitat/medium/medium (40%/30%/30%) then the overall rank would be medium (60%). In comparison the NESP method would rank the polygon as non-habitat.
  - DES used a precautionary approach by attributing the polygon with the highest regional ecosystem suitability category represented in the polygon (the 5% rule). For example, a heterogeneous polygon that consisted of 5% high and 95% low ranked regional ecosystems would be categorised as high rank. From an ecological perspective, if a polygon was heterogeneous then a koala is likely to use the favourable habitat components even if they occupy only a small proportion of the polygon.
  - For details see the report (DES 2020) or technical methods (DES 2020b).
- Habitat map "planning units" represented by 100ha hexagons. The documentation needs more information on how regional ecosystems, Maxent and koala records were translated to hexagons. This translation could be problematic as it will require a rule, such as simple majority or if polygon was more than 50% of a particular RE. We negated this problem for REs by attributing the RE polygons with koala habitat suitability. However, we had to overcome the problem of translating the Maxent values to the RE polygons.
- Maxent values translated to hexagons using centroid value only. Need to investigate sensitivity to allocation method. Compare with majority or threshold rule such as the 20% used by DES (2020). This threshold involved much discussion and investigation (sensitivity analysis) and was recommended to show sensitivity by CSIRO review.

- Maxent binomial (habitat/non-habitat) fixed cumulative 10 represents a very low threshold. It would be good to document the basis for these threshold choices and the sensitivity associated with them.
- In the development of the RE model, koala records were represented by a 1km buffer and not points. This means the record buffers would intersect many more, potentially non koala REs. It's unclear whether using points or buffers would make a difference to the model.
- It would be good to document more about the "changes in tree species utility classification" with some species "change to medium". How were they changed, from higher or lower utility...?
- Using the REDD field "RE_KEY" allows the sorting of regional ecosystems in numeric order which is easier to read than sorting as a text string.
- Would be good to document what variables were used in the Maxent models

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Prepared by :-
Harriet Preece
Biodiversity Assessment Team
Queensland Herbarium
Science and Technology Division
Department of Environment and Science

Date of request	2/11/2020
Requested by	Claire Runge, NESP
Request	Here are the habitat maps that we've been working on for Queensland. I have included the methods and classification scheme that I used and would be very happy to get expert feedback on this, preferably by 15 Nov if possible. Please keep this in house, it is still in draft form. Clair Runge
Date of this report	10/11/2020
Report Directory	\\nas01\EHP_Ecosystem_Outcomes\projects\Koala_SEQRP\Project_Management\requests\2020\201027_nesp_qld_habitat\nesp_model
Report File Name	NESP_Qld_koala_habitat_map_review.docx
Author(s)	Harriet Preece
Checked by	Lindsey Jones 9/11/2020
Approved by	Steven Howell
General location	Queensland-wide koala habitat (excluding SEQ regional planning area)

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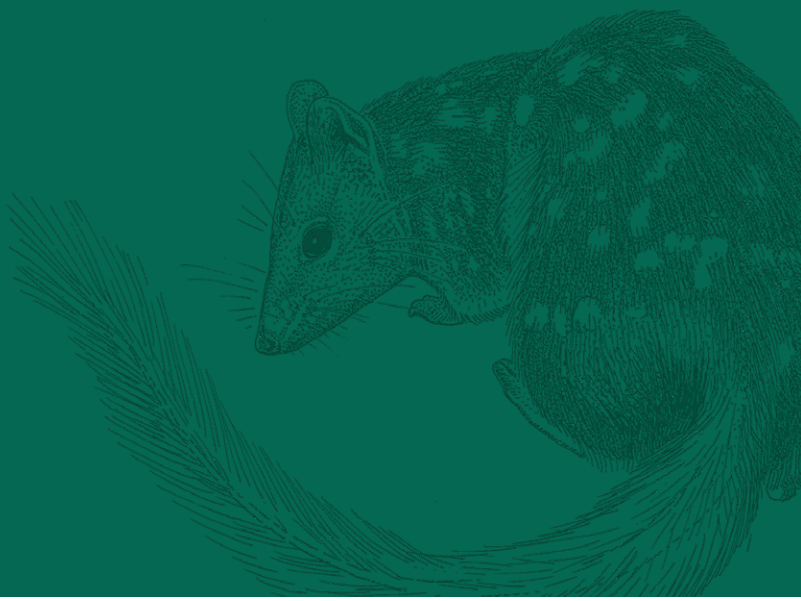
Koala. Image: Cassie Lafferty, Unsplash

Further information:
http://www.nespthreatenedspecies.edu.au



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