Eurobodalla Koala Habitat and Occupancy Project
Gilmore Electorate
Communities Environment Program 2019-2020
REPORT

Publisher: ***The Coastwatchers Association Inc www.coastwatchers.org.au***

The volunteer Eurobodalla Koala Project www.eurokoalas.com works on Yuin country. We acknowledge and thank local Elders and Local Aboriginal Lands Councils.

Smoking Ceremony at re-opening of Mogo Wildlife Park, February 2020

CONTENTS

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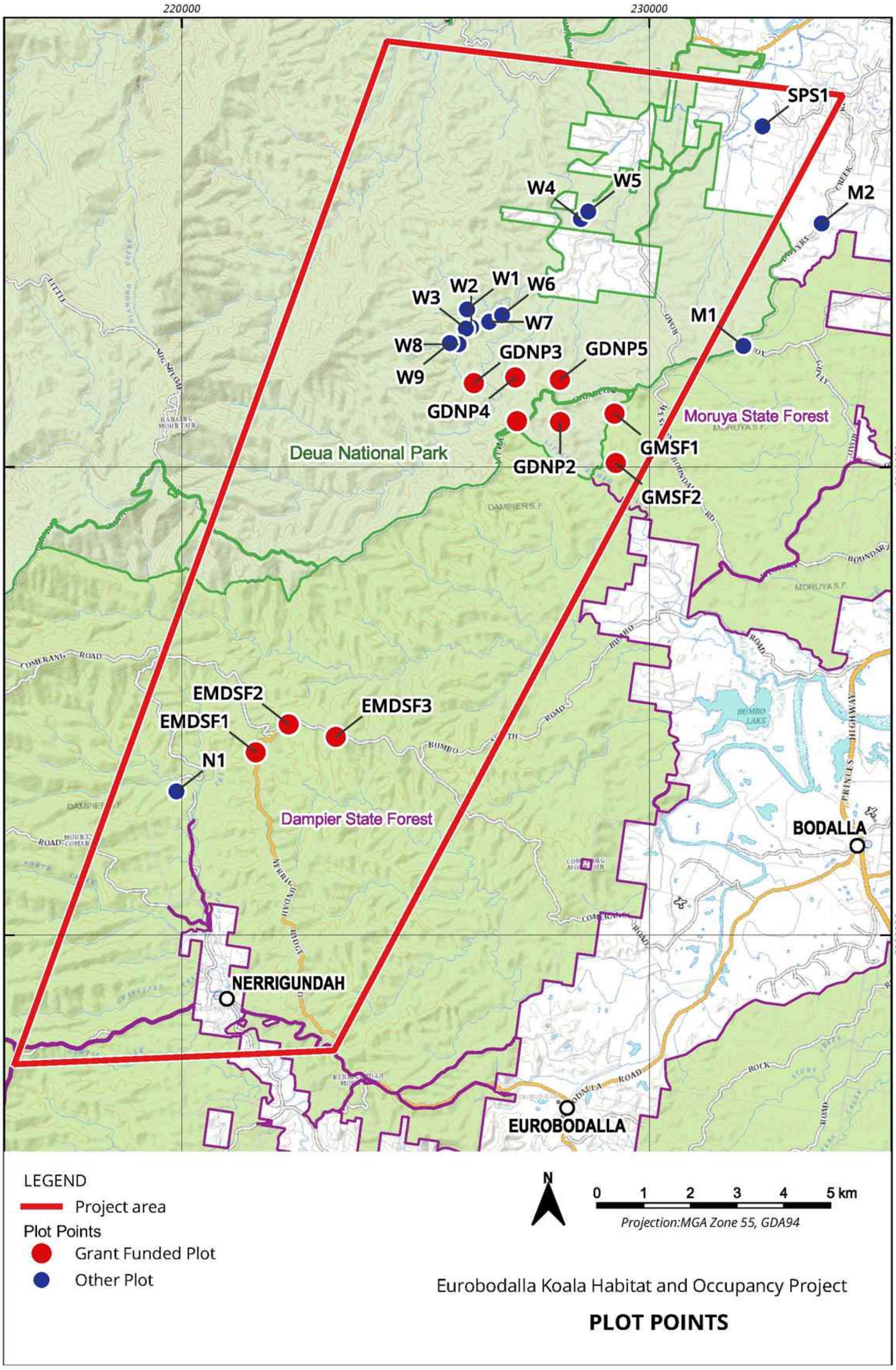
Credits

Please feel free to use our maps and photographs, but please credit us ("EKP").

INTRODUCTION

For the year 2020 the Commonwealth Government granted $2,800 to The Coastwatchers Association Inc (matched in-kind by Coastwatchers) under the Communities Environment Program.

The purpose of the grant was identification of koala habitat with a view to future koala population revival or reintroduction. The grant enabled ten close-scale plot surveys to ground-truth wider-scale modelling of potential koala habitat in the forested patch between Wamban and Nerrigundah.


220000
230000
6010000
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SPS1
M2
W4
W5
W2
W1
W6
W3
W7
W8
W9
GDNP3
GDNP5
M1
GDNP4
GDNP2
GMSF1
GMSF2
Moruya State Forest
Deua National Park
EMDSF2
EMDSF3
EMDSF1
N1
Dampier State Forest
BODALLA
NERRIGUNDAH
EUROBODALLA
LEGEND
Project area
Plot Points
Grant Funded Plot
Other Plot
N
0 1 2 3 4 5 km
Projection:MGA Zone 55, GDA94
Eurobodalla Koala Habitat and Occupancy Project
PLOT POINTS

Fire and COVID-19

Although the grant was made beforehand, the severe fires of the 2019-2020 summer made this work all the more important, firstly as a contribution to the economic and social recovery of the Eurobodalla, and secondly for the scientific purpose of ascertaining the fires' impact on the suitability of the project's use of the Regularised Grid Based Spot Assessment Technique (RGBSAT) for individual plot analysis. Estimating the survival and recovery of the habitat patch also became relevant. These catastrophic fires burned at high-to-very high intensity across most of the study patch, with the remaining quarter experiencing low-to-medium intensity fire.

Further disruptions to community and agency consultations, group gatherings and travel for fieldwork occurred because of the COVID-19 viral pandemic.

Fieldwork and the reporting deadline were postponed by six months to allow community and agency contacts time to recover as well as access and safety reasons. Amended planning for the fieldwork included additions to expected data collection such as the impact of the fire on eucalypt recovery or density, whether thinning/thickening of shade or understory were permanent and the need to look more closely at soil composition after hot fire.

BACKGROUND AND PREVIOUS RESEARCH

The forested patch between Wamban and Nerrigundah (partly Deua National Park, partly Moruya State Forest, mostly Dampier State Forest, with some small private holdings and crown land) was deemed significant because the last known evidence of koala presence in the Eurobodalla prior to 2020 was at Wamban Creek in the 2012-13 summer breeding season (roar recorded and scats found) and at Nerrigundah village in November 2013 (Byard/Thompson/Morgan pers comm).

Nerrigundah had readily visible koalas in the mid-20th Century (Burdett pers comm). Wamban has a previous recorded history of resident koalas affected by the fires of 1952 and 1968
[https://trove.nla.gov.au/newspaper/article/131672798?searchTerm=%20koalas%20Wamban&searchLimits=
Canberra Times article 24th September 1968_TROVE link]

The NSW BioNet repository "SEED" [http://www.bionet.nsw.gov.au/] contains historic records of koala sightings around Wamban (1968) and Nerrigundah (up to 2004). Local undocumented reports placed koalas at Gulph Creek and Nerrigundah Ridge Road around the year 2009.

Fresh koala scats at Wamban Creek 2013 – photo Candace Wirth

Preliminary observations suggested the patch is dominated by White Stringybark (Eucalyptus globoidea) and the southern-most occurrence in NSW of Smooth-barked Apple (Angophora costata).

Previous NSW OEH surveys in the Bega Valley Shire found White Stringybark was one of the preferred browse species for south-east low-density koalas and suggested White Stringybark might be more preferred during dry periods [Allen, Saxon and MacDougall 2010 and pers comm https://onedrive.live.com/?authkey=%21ABlgYHn9mqn4apQ&cid=9F1F0E4ED1B4D4A6&id=9F1F0E4ED1B4D4A6%2117436&parId=9F1F0E4ED1B4D4A6%211662&o=OneUp].

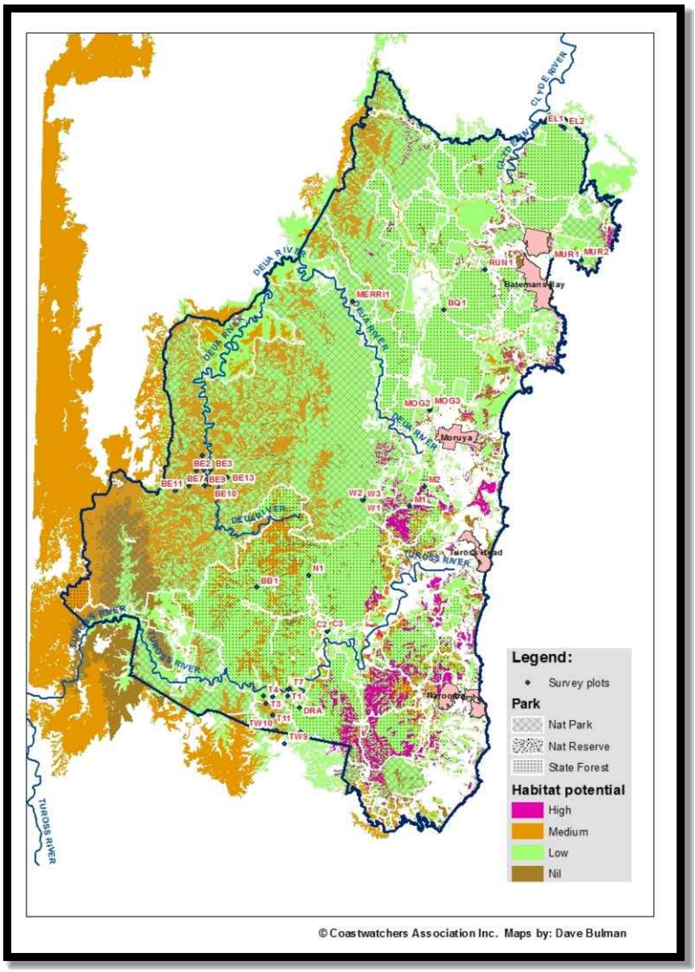
The NSW Government Review of Koala Tree Use Across NSW 2018 rates Smooth-barked Apple as "significant use" at Port Stephens for example [https://www.environment.nsw.gov.au/research-and-publications/publications-search/a-review-of-koala-tree-use-across-new-south-wales]
or
[https://onedrive.live.com/?authkey=%21ABYTi6Sl9i2HHOM&cid=9F1F0E4ED1B4D4A6&id=9F1F0E4ED1B4D4A6%2117434&parId=9F1F0E4ED1B4D4A6%211662&o=OneUp].

The Wamban-Nerrigundah patch might therefore offer a viable breeding corridor with potential home range habitat at each end.

In 2012-13 the Coastwatchers-funded Eurobodalla Koala Project had used ArcGIS to model and map potential habitat over the whole Eurobodalla LGA, collected local knowledge [www.coastwatchers.org.au/eurobodalla-koalas-project-pilot-study-report-2013/] and had undertaken twelve plot surveys in the vicinity of this Gilmore Electorate project [https://eurokoalas.files.wordpress.com/2021/01/w1-9-plus-m1-2-plus-n1-survey-datasheets_zip-file.zip].

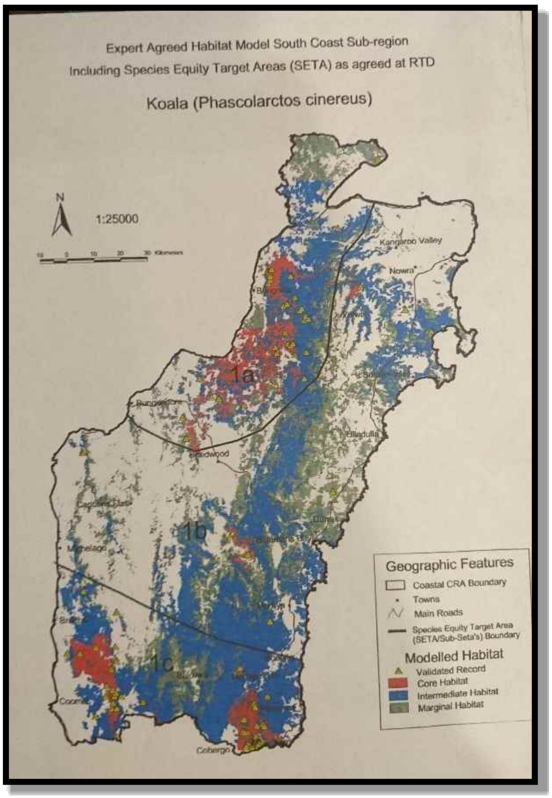
The map displayed a mix of “high”, some “medium” and mainly “low” quality “potential habitat” with the most promising at the Wamban end of the patch plus a smaller concentration at Nerrigundah.

Map of Modelled Habitat – 2013 – Eurobodalla Koala Project

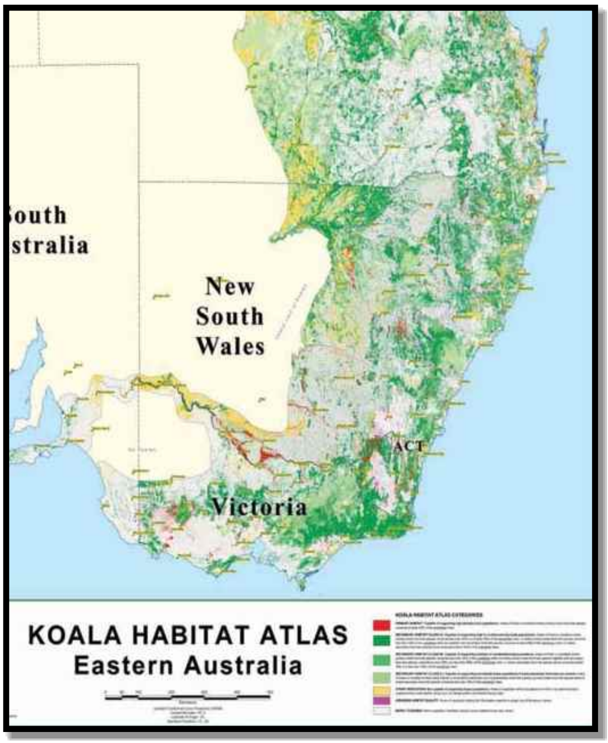


Other wider-scale modelling available at that time had suggested either “intermediate” quality habitat across the whole patch (CRA below), or a mix (AKF below).

Modelling Areas of Habitat Significance for Vertebrate Fauna and Vascular Flora in the Southern CRA Region - A project undertaken as part of the NSW Comprehensive Regional Assessments, February 2000



Australian Koala Foundation



Most of the 2012-13 plot survey results tended to confirm either the Eurobodalla Koala Project Pilot Study proposition (based on eucalypt species as the only factor) that viable remnant habitat is present [Pilot Study op cit. Pp 38, 59-61 www.coastwatchers.org.au/eurobodalla-koalas-project-pilot-study-report-2013/] or other research [Gow-Carey 2012, Pp 38-43 https://eurokoalas.files.wordpress.com/2021/01/h_gow-carey_thesis-copy-2020_03_04-11_50_23-utc.pdf] showing koala-preferred tree species such as Grey Ironbark (Eucalyptus paniculata), some Woollybutt (Eucalyptus longifolia) and Coast Grey Box (Eucalyptus bosistoana) are present.

Three of those plots had been randomly located and the remainder focused on the area around the confirmed 2012-13 koala record at Wamban Creek. The Eurobodalla Koala Project's 2013 modelled map was part of a pilot study only, and did not have the benefit of the subsequent testing of additional habitat factors during the Bendethera expedition [http://www.coastwatchers.org.au/bendethera-koala-habitat-survey-report/] or the benefit of documented evidence used for koala browse species listings in the 2018 NSW Government Review, op cit [https://www.environment.nsw.gov.au/research-and-publications/publications-search/a-review-of-koala-tree-use-across-new-south-wales].

So, the Gilmore Electorate *Eurobodalla Koala Habitat and Occupancy Project 2019-2020* was now needed for an adequate test of habitat quality in the precise map polygon identified.

<u>Advances in GIS, GPS and Koala Feed Species Data</u>

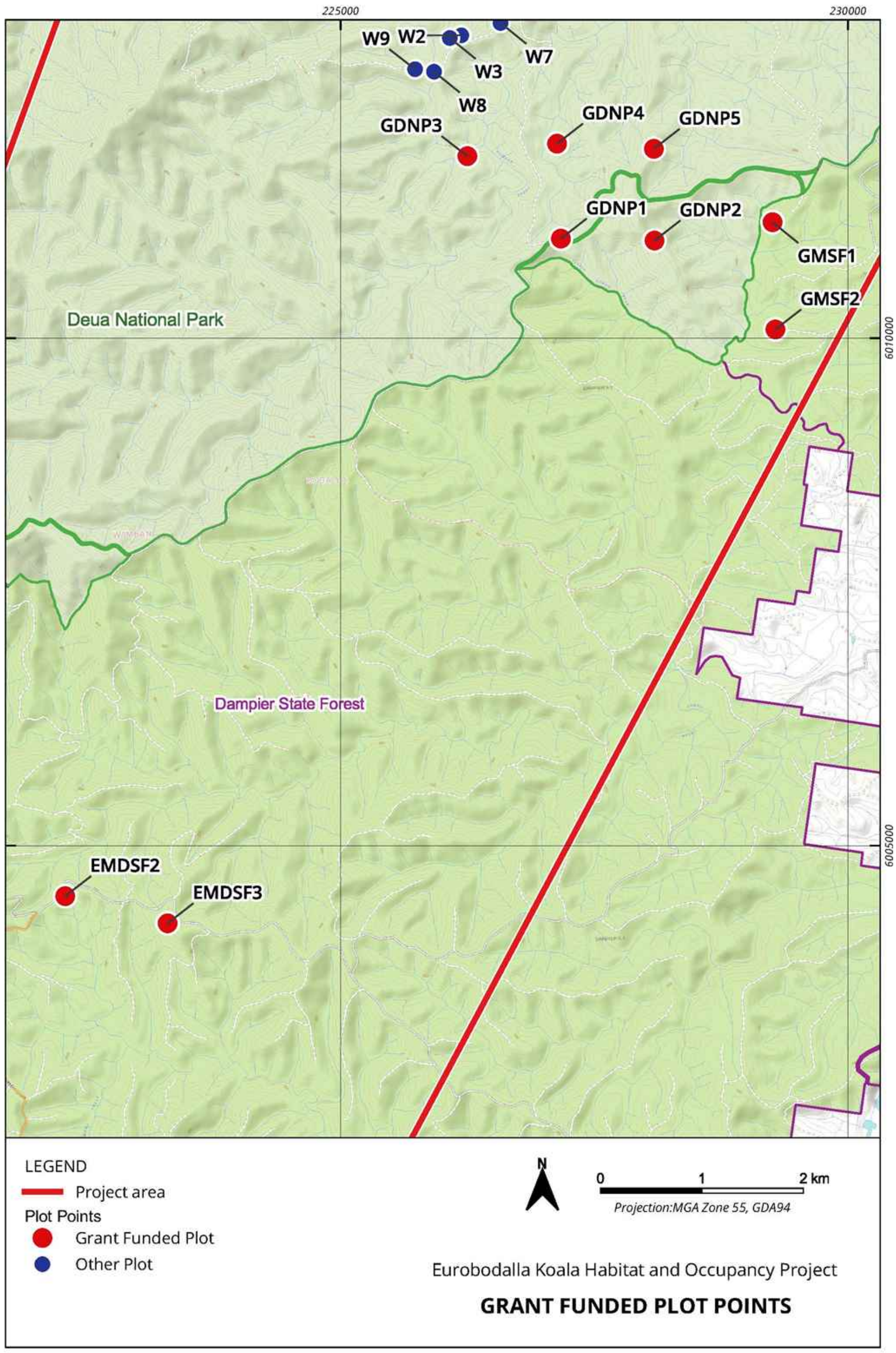
Since 2012-13 when the Eurobodalla Koala Project volunteers had to purchase and learn *ArcGIS*, *ANUCLIM* and *Garmin*, make their own maps using minimal data, and subjectively interrogate miscellaneous research and cross-reference it manually, substantial advances have occurred in publicly accessible GIS freeware, GPS apps, and the availability of data layers and interactive maps. The project now uses *QGIS*, the *Avenza Maps* app, the *Australia Topo Maps* app and the newly developed post-fire *Nest Forms – survey builder Bush Recovery* app. Numerous datasets are now accessible in the NSW SEED repository, op cit [http://www.bionet.nsw.gov.au/] spanning relevant koala habitat factors such as vegetation types, topography, waterways, soils, weather, fire and land use. The NSW Government Review of Koala Tree Use [op cit] was published in 2018, updating evidence-based conclusions about the patterns of use of eucalypt species by koalas within regions and across the whole state with consequent updates in government policy (eg SEPP44, which generated a high-profile party-political incident in September 2020). Although very little of the NSW Government Review's raw data came from the Eurobodalla Local Government Area, transferring its koala tree usage findings from the intensively surveyed Bega Valley Shire and from other regions beyond the South Coast to the Wamban-Nerrigundah polygon, played a key part in the findings of this Gilmore Electorate study.

The *Eurobodalla Koala Habitat and Occupancy Project 2019-2020* has been able to query and cross-reference amongst these newer resources.

FIELDWORK

The 2020 Plot Surveys

Seven plots were surveyed in the Gilmore Electorate at the northern end and three plots in the Eden-Monaro Electorate to the south.



Plot numbers were coded as Gilmore Deua National Park (GDNP1-5), Gilmore Moruya State Forest (GMSF1-2) and Eden-Monaro Dampier State Forest (EMDSF1-3).

Their GPS coordinates (UTM 55 H; errors +/-5m to +/-9m) are as follows.

Plot Number	Easting	Northing
GDNP1	0767962	6011131
GDNP2	0768882	6011055
GDNP3	0767092	6011998
GDNP4	0767980	6012063
GDNP5	0768931	6011957
GMSF1	0770054	6011164
GMSF2	0770017	6010108
EMDSF1	0761948	6004413
EMDSF2	0762687	6004967
EMDSF3	0763678	6004638

The primary data collection was recorded on Datasheet 1, a modified version of the RGBSAT (Regularised Grid Based Spot Assessment Technique) datasheet commonly used for surveys and analysis of koala habitat occupancy. The Eurobodalla Koala Project Pilot Study (op cit) had tested the adaptation of this datasheet to the purpose of ground-truthing wider potential habitat patches even when koalas are not present, and suggested it was worthwhile, providing inputs on multiple habitat factors capable of being statistically analysed.

The following is an example of a completed Datasheet 1.

Dampier State Forest

Research Permit Number RES100046

MISCELLANEOUS PLOTS KOALA SURVEY 2020_

MODIFIED DATASHEET

Site Number__EMDSF1	**Recorder__Ross Heazlewood**	**Time__10.14**	**Date__15/10/2020**
Easting 0761948	**Northing 6004413**	**Datum** UTM 55	**GPS Error +/-8m**
Altitude 342m	**Steepness 15deg** **Aspect** N	**Shade** Open	
Weather History Temperate	**Disturbance History** Hot **wildfire; logging probably 10 yrs ago**		
Geology (Granitic, Metasediment or Bassalt?) **Metased**	**Code on Geo map Dmew**		
Soil Depth(Hardly Any, Some Depth or Deep?) **SD**	**Type** (Sndy, Sndy Loam, Lm?) **SL**	**Sample collected? YES**	
Species Richness est (High, Medium, Low) **M**	**Tree Canopy Cover** est (Thick, Medium, Thin) **Thin**		
Trees recorded clockwise on N bearing from Centre Tree	**Plot Radius 23.4m**	**SAT Criteria 3**	

	TSP	**DBH**	**Koala**	**KFP**
1	Eglo	910		
2	Esie	735		
3	Esie	550		
4	Angflo	336		
5	Esie	330		
6	Esie	469		
7	Esie	363		
8	Esie	355		
9	Angflo	334		
10	Esie	370		
11	Angflo	652		
12	Eglo	540		
13	Eglo	580		
14	Esie	590		
15	Eglo	220		
16	Ecyp	388		
17	Eglo	380		
18	Esie	305		
19	Esie	218		
20	Esie	565		
21	Eglo	575		
22	Eglo	440		
23	Esie	652		
24	Esie	210		
25	Esie	370		
26	Eglo	313		
27	Esie	290		
28	Esie	610		
29	Esie	325		
30	Ecyp	545		

1haveseenkoala 2haveseenpelle 3gridplot

Groundcover ease of searching

Easy

NB: Small understorey

Koala information

Pellet Age Old Mixed Fresh

A/level______/______=______% ie pell/trees

Comments (incl tracks/scratches)

Information about other Fauna

Nature of Observation

P: Pellets, D: Digs, O: Observ, N: Nest, C: Call, M: Mound

Wallaby		**BT Possum**	
EG Kangaroo		**RT Possum**	
LN Bandicoot		**YB Glider**	
LN Potoroo		**Lyrebird**	
Wombat		**Bell minor**	
Rabbit		**Deer**	
G.Glider		**Other**	See below

No of Bandi/Potoroo digs within 5m of CT _

Unsure? - Use Comments

Team Members

Keith	Ross
Craig	Charlie
Kylie	

Transect			
	Time	**Eastings**	**Northings**
Start	10.14		
Finish	11.2		
Pellet sites			
Pellet sites			

OTHER COMMENTS

Cicadas; 10cm Jacky (Mountain) Dragon; Emp Gum Moth; Flowering Gonfuds; Tree 4 about to flower; Trees 16 & 30 - ID difficulty Ecyp? Trees 9 & 11 in bud; 14 x smaller plants & 4 x birds listed on separate sheet.

Data Entry Information	**Date**
Checked by	
Entered by	

For each plot, Datasheet 1 was also converted and sent to the NSW Department of Planning, Industry and Environment for inclusion in its comprehensive database.

Datasheet 2 and the *NestForms* app, used to record the impact of fire on the plots, are described later in "FIRE" and "FINDINGS – Fire".

The full collection of Datasheets 1 and 2, Additional Information Sheets and photographs may be viewed at the following links:

Set 1 EMDSF 1 to 3 Photos
https://eurokoalas.files.wordpress.com/2021/01/set-1-emdsf-1-to-3-photos.zip

Set 2 EMDSF Photos Google Drive Link
https://eurokoalas.files.wordpress.com/2021/01/set-2-emdsf-1-to-3-photos-google-drive-link.docx

Set 3 EMDSF 1 to 3 Photos
https://eurokoalas.files.wordpress.com/2021/01/set-3-emdsf-1-to-3-photos.zip

Set 4 EMDSF 1 to 3 Photos
https://eurokoalas.files.wordpress.com/2021/01/set-4-emdsf-1-to-3-photos.zip

Set 5 EMDSF 1 to 3 Photos
https://eurokoalas.files.wordpress.com/2021/01/set-5-emdsf-1-to-3-photos.zip

Link to GDNP Photo_Instagram
https://www.instagram.com/p/CDF3NFlFRl_/?utm_source=ig_web_button_share_sheet

Set A GDNP 1 and 2 Photos
https://eurokoalas.files.wordpress.com/2021/01/set-a-gdnp-1-and-2-photos.zip

Set B GDNP 1 to 5 Photos
https://eurokoalas.files.wordpress.com/2021/01/set-b-gdnp-1-to-5-photos.zip

Set C GDNP 1 and 2 Photos
https://eurokoalas.files.wordpress.com/2021/01/set-c-gdnp-1-and-2-photos.zip

Set D GDNP 4 and 5 Photos
https://eurokoalas.files.wordpress.com/2021/01/set-d-gdnp-4-and-5-photos.zip

EMDSF Datasheets and Additional Information
https://eurokoalas.files.wordpress.com/2021/01/emdsf-datasheets-and-additional-information.zip

GDNP Datasheets and Additional Information
https://eurokoalas.files.wordpress.com/2021/01/gdnp-datasheets-and-additional-information.zip

GMSF Datasheets
https://eurokoalas.files.wordpress.com/2021/01/gmsf-datasheets.zip

Near Plot GDNP 2
Photo: Nick Hopkins

PRE-EXISTING AND RELATED DATA ON THE PATCH

Vegetation Types and Eucalypt Species

Publicly available Forestry Corporation NSW Forest Type Maps and some history and condition data for thirteen Dampier State Forest compartments within the study patch were examined. These can be found at https://www.forestrycorporation.com.au/operations/harvest-plans/south-coast. They display substantial amounts of "Coastal Dry Forest" (see below), Ash (probably mainly Eucalyptus sieberi), Yellow Stringybark (Eucalyptus muelleriana), and Brown Barrel (Eucalyptus fastigata). [*Note Compartment 3108, below, also contains White Stringybark (E globoidea) and Manna Gum (E viminalis).*]

For these tree species, the NSW Government Review of Koala Tree Use 2018 [op cit] pp16ff indicates documented koala use as follows:

- E sieberi: High (Central Coast); Significant (South Coast); Irregular (Central & Southern Tablelands)
- E muelleriana: High (South Coast); Low (Central Coast)
- E fastigata: Low (South Coast)
- E globoidea: High (South & Central Coasts); Significant (North Coast); Irregular (Central & Southern Tablelands)
- E viminalis: High (Central Coast, Northern, Central & Southern Tablelands); Irregular (South Coast & North Coast) - documented as a primary koala species in Victoria (eg Strzeleckis and Brisbane Ranges NP) [Pilot Study op cit, pp16, 21 & 78ff].

The Forestry Corporation NSW Hardwood Forests Division Forest Management Plan

[https://www.forestrycorporation.com.au/__data/assets/pdf_file/0011/669008/hardwood-forests-forest-management-plan.pdf] details "Coastal Dry Forest" as follows:

> *Dry coastal hardwoods are the most widely distributed forest communities in coastal NSW and stands comprise mosaics of different species. The most commonly occurring species are grey gum (Eucalyptus propinqua), grey ironbark (E. paniculata), coastal grey and steel box (E. moluccana, bosistoana, rummeryi), red/white mahogany (E. resinfera, E. acmenoides/umbra), stringybarks (E. globoidea, cameronii, sparsifolia) and smooth-barked apple (Angophora costata). Many of the species that comprise the dry coastal forests are highly valued for their durability. In general however, higher rates of internal wood defects and slower growth rates mean these forests are of less commercial value than the other more productive forests described in this plan. Silviculture is generally much more flexible in these forests, because most species regenerate easily. Direct establishment of seedlings may occur in some of the more mesic stands, though regeneration from lignotubers and coppice is more common in the drier phases. In this way, dry hardwood stands have a very similar response to disturbance as the spotted gum types and will be similarly managed from a silvicultural perspective. [p.18]*

Although these forest types are of "less commercial value", the presence of species especially Eucalyptus bosistoana, Eucalyptus globoidea and to a lesser extent Eucalyptus propinqua, Eucalyptus paniculata and Angophora costata [NSW Government Review of Koala Tree Use 2018, op cit] make them potentially useful as low-density koala habitat.

For the tree species mentioned here but not already listed above for harvest plans and Compartment 3108, the NSW Government Review 2018 [op cit] indicates documented koala use as follows:

- E propinqua: High (north Coast); Significant (Central Coast)
- E paniculata: High (Central Coast)
- E moluccana: Significant (North & Central Coasts); Irregular (northern Tablelands)
- E bosistoana: High (South & Central Coasts)
- E rummeryi: Irregular (North Coast)
- E resinifera: High (North Coast); Significant (Central Coast)
- E acmenoides/umbra: Significant (North Coast); Irregular (Central Coast)/Low (North Coast); Irregular (Central Coast)
- E cameronii: Low (North Coast)
- E sparsifolia: Irregular (Central Coast)
- Angophora costata: Significant (North Coast); Low (Central Coast)

The harvest plan example Compartment 3108 (approved 30/01/2014) within this study's polygon of interest contains the following outline:
"Overstorey dominated by silvertop ash, stringybark (white and yellow), brown barrel and manna gum.
Ridge tops and gently sloping areas have undergone heavy STS silviculture in the early 70's. The steeper areas were subject to less intensive harvest and some areas have remained unharvested.
The ridgetops comprise of an even aged stand of advanced regrowth silvertop ash of good form and vigour. These stands are generally suited to a lighter cut to concentrate growth on the retained stems into future high-quality sawlogs.
The remaining area comprises an uneven aged mature to overmature stand of trees which are reaching their end point. This stand would benefit from a heavy cut to promote regeneration."

The NSW OEH Threatened Species site [https://www.environment.nsw.gov.au/threatenedspeciesapp/profileData.aspx?id=10616&cmaName=South+East+Corner] lists numerous "vegetation associations" for the koala in the south-east corner (and nearby) which feature eucalypt species found in the Wamban-Nerrigundah research polygon. Cross-referencing these with the other sources reinforces the perception that the research patch is suited to koalas.

Selections are as follows:

Southern Hinterland Dry Sclerophyll Forests

- *Silvertop Ash - Messmate - Mountain Grey Gum shrubby open forest of the hinterland ranges, southern South East Corner Bioregion*
- *White Stringybark - Maiden's Gum grassy open forest on granitic foothills, southern South East Corner Bioregion*
- *White Stringybark - Mountain Grey Gum - Maiden's Gum grassy open forest on granitic foothills and ranges, southern South East Corner Bioregion*

South Coast Wet Sclerophyll Forests

- *Mountain Grey Gum - Yellow Stringybark moist shrubby open forest in gullies of the coastal ranges, northern South East Corner Bioregion*
- *Mountain Grey Gum ferny tall moist forest on coastal ranges, southern South East Corner Bioregion*
- *River Peppermint - Rough-barked Apple moist open forest on sheltered sites, southern South East Corner Bioregion*
- *Sydney Peppermint - Spotted Gum - Lilly Pilly wet forest in gullies of the coastal foothills, northern South East Corner Bioregion and southern Sydney Basin Bioregion*
- *Yellow Stringybark - Coast Grey Box shrubby open forest on the coastal ranges, South East Corner Bioregion*
- *Yellow Stringybark - Mountain Grey Gum moist shrubby open forest on coastal ranges, southern South East Corner Bioregion*

<u>South East Dry Sclerophyll Forests</u>

- *Ironbark - Woollybutt - White Stringybark open forest on coastal hills, South East Corner Bioregion*
- *Messmate dry shrubby forest on sandstone, far southern South East Corner Bioregion*
- *Mountain Grey Gum - White Stringybark open forest on sandstone mountain slopes, far south west South East Corner Bioregion*
- *Red Bloodwood - Silvertop Ash - White Stringybark heathy open forest on coastal foothills, southern South East Corner Bioregion*
- *Silvertop Ash - Black She-oak shrubby open forest on hills of the Bega Valley, South East Corner Bioregion*
- *Silvertop Ash - Blue-leaved Stringybark - Red Bloodwood dry shrubby open forest on ridges of the hinterland foothills, northern South East Corner Bioregion*
- *Silvertop Ash - Blue-leaved Stringybark - Woollybutt shrubby open forest on coastal foothills central South East Corner Bioregion*
- *Silvertop Ash - Blue-leaved Stringybark shrubby open forest on hinterland hills, far southern South East Corner Bioregion*
- *Silvertop Ash - Blue-leaved Stringybark shrubby open forest on ridges, north east South Eastern Highlands Bioregion*
- *Silvertop Ash - Broad-leaved Peppermint dry shrub forest of the South Eastern Highlands Bioregion*
- *Silvertop Ash - Mountain Grey Gum shrubby dry open forest on ridges in Wadbilliga NP, South East Corner Bioregion*
- *Silvertop Ash - Narrow-leaved Peppermint open forest on ridges of the eastern tableland, South Eastern Highlands Bioregion and South East Corner Bioregion*
- *Silvertop Ash - Rough-barked Apple shrubby open forest on the hinterland hills, far southern South East Corner Bioregion*
- *Silvertop Ash - White Stringybark shrubby open forest of the escarpment ranges, southern South East Corner Bioregion*
- *Silvertop Ash open forest on exposed ridges of the escarpment ranges, far southern South East Corner Bioregion*
- *Silvertop Ash shrubby open forest on escarpment ridges, central and northern South East Corner Bioregion*
- *White Stringybark - Narrow-leaved Peppermint dry open forest on hinterland hills, far south of the South East Corner Bioregion*
- *Yellow Stringybark - Mountain Grey Gum shrubby open forest on slopes of the hinterland ranges, southern South East Corner Bioregion*
- *Yellow Stringybark - Silvertop Ash open forest on dry slopes of the escarpment ranges, northern South East Corner Bioregion*

Eastern Riverine Forests

- *River Peppermint - Rough-barked Apple - River Oak herb/grass riparian forest of coastal lowlands, southern Sydney Basin Bioregion and South East Corner Bioregion*

Grassy woodlands

- *Coastal Valley Grassy Woodlands*
  - *Forest Red Gum - Coast Grey Box shrubby open forest on steep hills in the Bega Valley, South East Corner Bioregion*
  - *Forest Red Gum - Rough-barked Apple - White Stringybark grassy woodlands on hills in dry valleys, southern South East Corner Bioregion*
  - *Woollybutt - White Stringybark - Forest Red Gum grassy woodland on coastal lowlands, southern Sydney Basin Bioregion and South East Corner Bioregion*

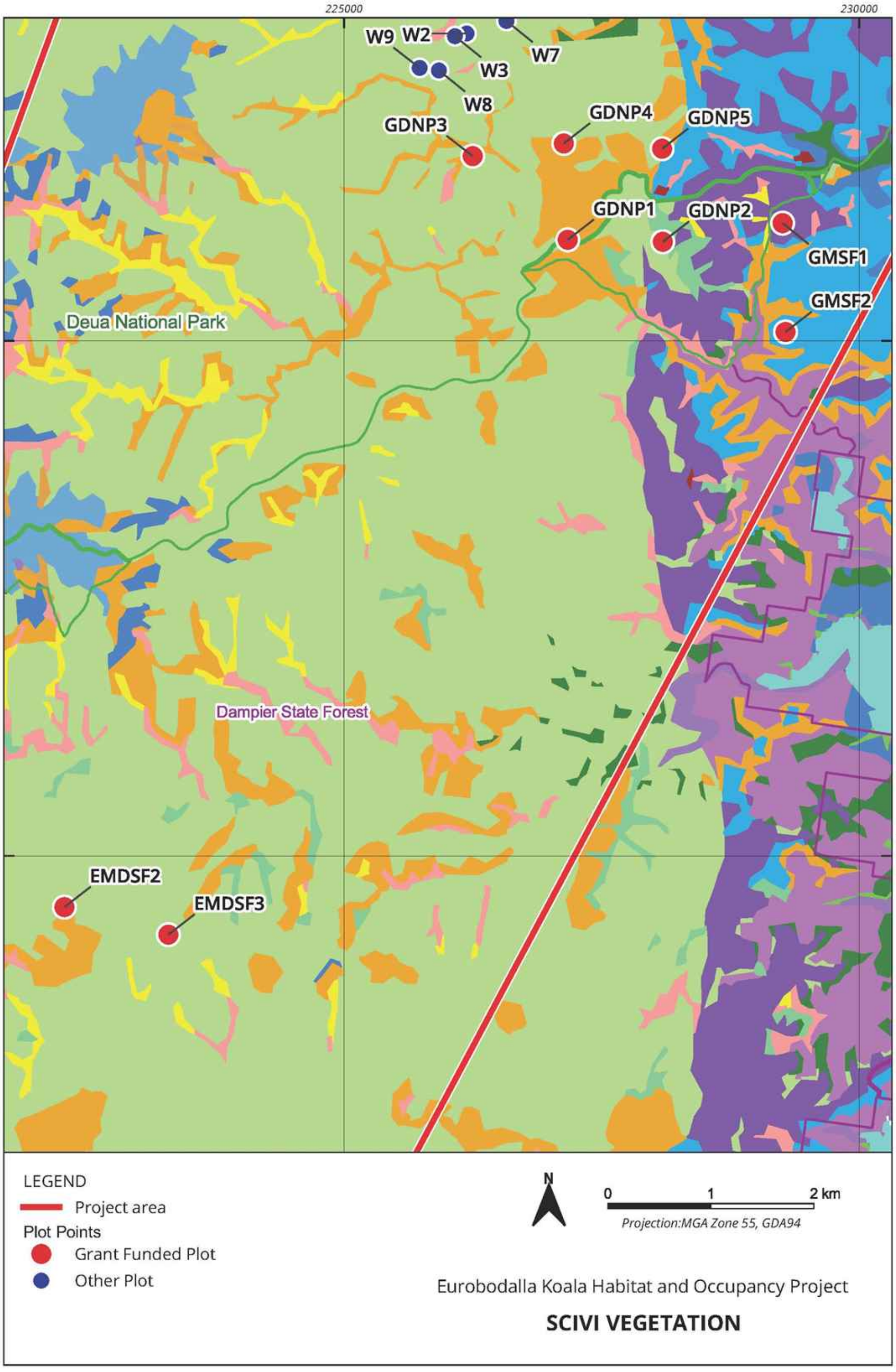
Southern Lowland Wet Sclerophyll Forests

- *Coast Grey Box - Mountain Grey Gum - stringybark moist shrubby open forest in coastal gullies, southern South East Corner Bioregion*
- *Spotted Gum - Grey Ironbark - Woollybutt grassy open forest on coastal flats, southern Sydney Basin Bioregion and South East Corner Bioregion*
- *Spotted Gum - White Stringybark - Burrawang shrubby open forest on hinterland foothills, northern South East Corner Bioregion*

Southern Escarpment Wet Sclerophyll Forests

- *Brown Barrel - Mountain Grey Gum - Blanket Bush moist very tall open forest of the southern escarpment ranges, South Eastern Highlands Bioregion and South East Corner Bioregion*
- *Messmate - Mountain Grey Gum moist open forest of granitic foothills, southern South East Corner*
- *Mountain Grey Gum - Brown Barrel very tall moist forest on escarpment ranges, central and southern South East Corner Bioregion*
- *River Peppermint - Narrow-leaved Peppermint open forest on sheltered escarpment slopes, Sydney Basin Bioregion and South East Corner Bioregion*
- *White Ash - Silvertop Ash - Brown Barrel shrubby open forest of the escarpment ridges, South Eastern Highlands Bioregion and South East Corner Bioregion*

The "SCIVI" classifications [https://eurokoalas.files.wordpress.com/2021/01/scivi-tozer-et-al-7-pdf-docs.zip] which provide comprehensive detail on vegetation types, were used as part of this project's analysis. We targeted SCIVI classification types located around the whole Wamban-Nerrigundah research polygon.



Like the *Threatened Species List* the *SCIVI classifications* feature suitable koala browse eucalypt species according to the other research.

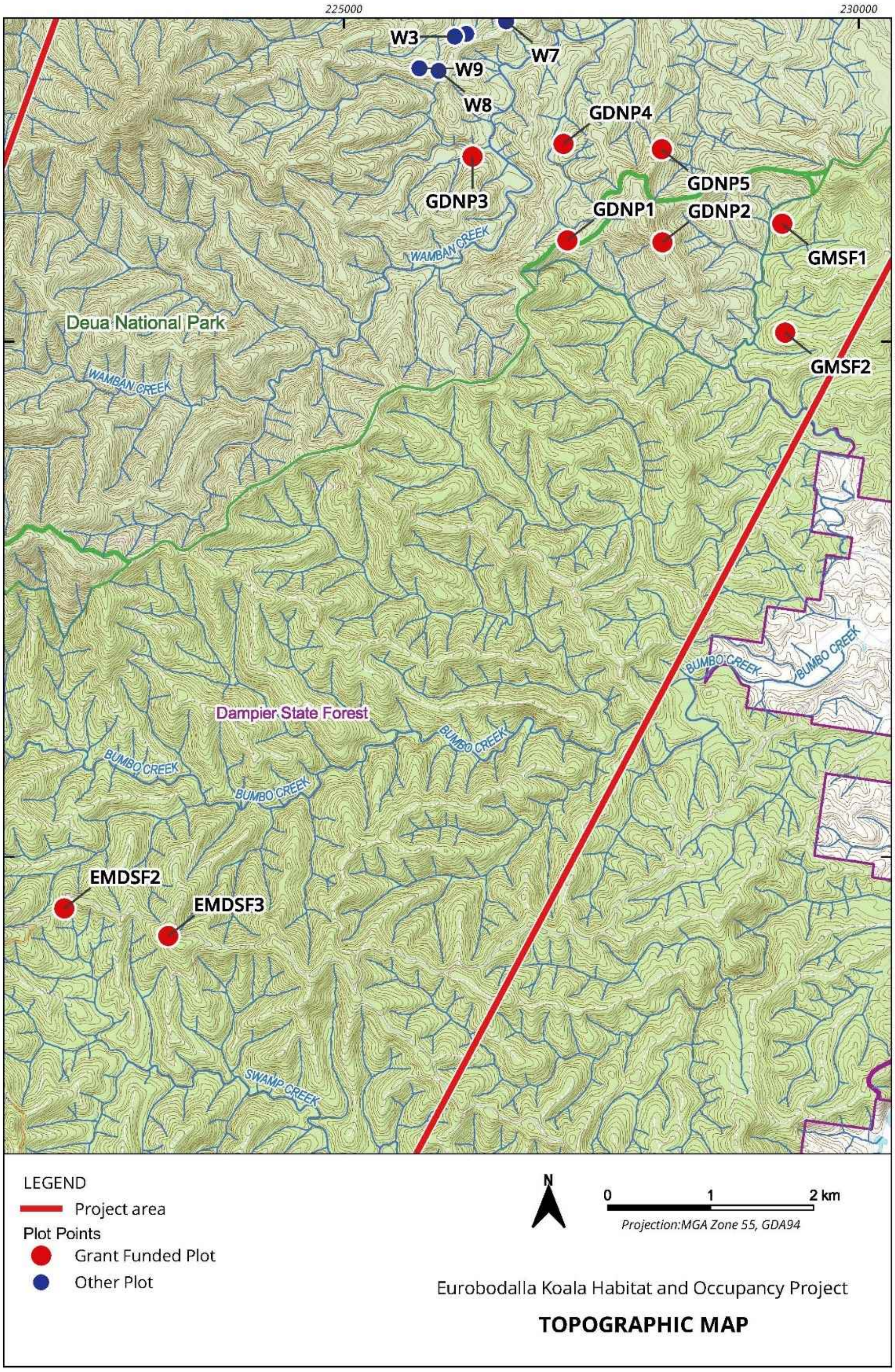
Eucalypts are listed in the SCIVI classifications as part of their positive diagnostic species. These are replicated in full at "ANALYSIS - Suitability of Eucalypt Species - Cross-referencing SCIVI Vegetation Types with Koala Tree Use Survey", below.

Extract from NSW Government Review 2018 [op cit] concerning judgements about habitat quality according to tree species usage

> '*An evidence-based review of koala tree use across New South Wales* - 40 occupying habitats that have been impacted by human disturbance to varying degrees. *KMA 3 (South Coast)* - Based on these studies, three species from the eucalypt sub-genus Symphyomyrtus were designated regional high use species (woollybutt E. longifolia, mountain grey gum E. cypellocarpa, red ironbark E. tricarpa) along with one from the sub-genus Eucalyptus (white stringybark E. globoidea). These species appear to be regionally important as potential indicators of koala habitat quality and their presence may elevate the use of associate species in their neighbourhood. However, recent work by Stalenberg et al. 2014 suggests that in some parts of this KMA, particularly locations of low site quality, the concepts of preferred koala tree species, and eucalypt sub-genera, may be less well-defined. In such locations, and similarly to suggestions for koala tree use in parts of KMA 2 (Central Coast), tree diversity and quality appear to become increasingly important and koalas may be trading and balancing between leaf nutrients and leaf toxins and spreading tree use across a diverse range of available species [e.g. Stalenberg et al. 2014, Chris Allen (OEH Merimbula) pers. comm.].'

(In its 2012-13 Wamban plots, the Eurobodalla Koala Project had not found any E tricarpa but Stalenberg's work suggests it might not matter.)

WEATHER, TOPOGRAPHY, SHADE AND WATER



Weather
Adams-Hosking's "highest probability of occurrence" ratings
[https://eurokoalas.files.wordpress.com/2021/01/adams-hosking-et-al-modelling-climate-change-impacts.docx]
appear to be matched by the temperature and rainfall history of the Wamban-Nerrigundah patch. All the plot survey datasheets record weather history as "temperate". Like the rest of south eastern Australia however, a climatic warming trend threatens.

Prior to the fires there had been drought, so the landscape had dried out badly. This would have made it already difficult for any koalas persisting in the area since the evidence of 2013.

After the fires there was good rain.

Altitude
The Wamban-Nerrigundah patch sits well below the old 800-metre altitude ceiling for koalas, once commonly presumed until examples like the 1,000-metre populations at Numeralla and the Blue Mountains were studied (Allen, pers comm).

This project's fieldwork ranged from altitude 110 metres (Plot GMSF2) to 390 metres (Plot EMDSF3).

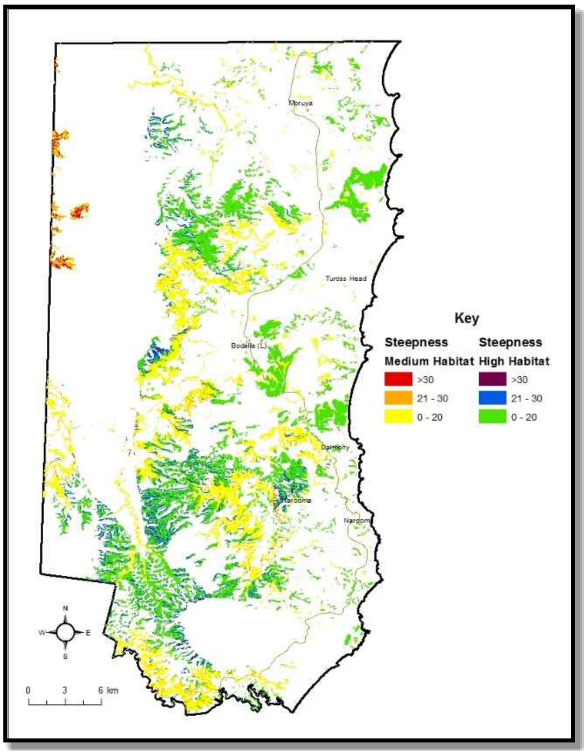
Slope
Cited in the Bendethera Report [op cit] Norton & Neave (1996) found 90% of koala sightings occurred on slopes of less than 20 degrees. Braithwaite (1983) suggested the best koala habitat is flat topography or gullies.

Slopes recorded in the Wamban-Nerrigundah plot survey datasheets were:

GDNP1 – 20 degrees
GDNP2 – 35 degrees
GDNP3 – 30 degrees
GDNP4 – 35 degrees
GDNP5 – 30 degrees
GMSF1 – 30 degrees
GMSF2 – 15 degrees
EMDSF1 – 15 degrees
EMDSF2 – 30 degrees
EMDSF3 – 5-10 degrees

In 2013 the Eurobodalla Koala Project had generated a map overlaying three slope scales on its preliminary potential habitat model. The Wamban-Nerrigundah patch is in the green and yellow patches at mid-top-left:

Map by Chris Malam



Aspect, Shade and Proximity to Permanent Water

Hammond (1997) [https://eurokoalas.files.wordpress.com/2021/01/hammond-1997-zip.zip] et al suggest Northerly or Westerly aspects are desirable, shade plays a part in habitat, and permanent water within a kilometre is optimal.

Shade and aspect for each Wamban-Nerrigundah plot were recorded as follows:

Plot Number	***(Post-fire)*** **Shade Recorded**	Aspect Recorded
GDNP1	Dappled	North North-East
GDNP2	Dappled	North East
GDNP3	Dappled	North
GDNP4	Dappled	North-West
GDNP5	Dappled	East North-East
GMSF1	Dappled	West
GMSF2	Dappled	North-West
EMDSF1	Open	North
EMDSF2	Dappled	South-East
EMDSF3	Open	North

The most reliable water in the area is Wamban Creek, Little Bumbo Creek, Gulph Creek and perhaps Swamp Creek. The survey plots are near minor tributary gullies, which are usually dry. Movement between the reliable creeks would require koalas to cross dry sections of up to several kilometres.

DISTURBANCE

Fire is examined in detail below.

Otherwise, the main 20th+ Century disturbance factor in the Wamban-Nerrigundah patch is **logging**. The great bulk of the patch is State Forest and National Park.

Plot survey records for disturbance were as follows:

GDNP1 – Wildfire
GDNP2 – Fire – medium intensity
GDNP3 – Wildfire <1 year
GDNP4 – Wildfire
GDNP5 – Wildfire
GMSF1 – Forestry; Wildfire
GMSF2 – Forestry; Wildfire
EMDSF1 – Hot Wildfire; Logging probably 10 years ago
EMDSF2 – Wildfire; Logged 15 years ago
EMDSF3 – Hot Wildfire; Logged 15 years ago

Historical clearing for private properties on the more fertile lands at the Wamban and Nerrigundah nodes, stands out as a factor especially as these would seem to be the locations for potential home ranges.

Hammond [op cit 1997] studying the area between Jervis Bay and Batemans Bay, concluded there are very few areas presenting high quality habitat. He suggested the lack of areas with high-quality nutrient status, combined with the concentration of clearing in high-nutrient areas (despite the small amount of clearing apparent when the whole landscape is overviewed), appear to be the strongest causal factors for lack of koala sightings on the NSW South Coast. Presumably this accounts for the extremely low-density koala population in the Eurobodalla, apparently more sparse since the mid-20th Century [Pilot Study, op cit].

Dieback is discussed by Chris Allen at [https://eurokoalas.files.wordpress.com/2021/01/enquiry-submission_chris-allen_sub35-2020_08_23-07_53_00-utc.pdf] and is often raised as an underappreciated factor by the blogger Robert Bertram [https://eurokoalas.files.wordpress.com/2021/01/p.16-bertram-blog-re-translocation-plans-plus-the-dieback-argument.docx].

GEOLOGY AND SOIL

Underlying Geology

Norton & Neave (1996) suggest the best koala habitat is on basalt or alluvium. Our plot surveys record geology as "Metasediment", the usual Far South Coast hinterland descriptor.

The potential breeding corridor in the Wamban-Nerrigundah patch lies over geological zones *Dmew* (sandstone/Merrimbula Group) and *Dmeb* (Clastic sedimentary rock/Merrimbula Group).

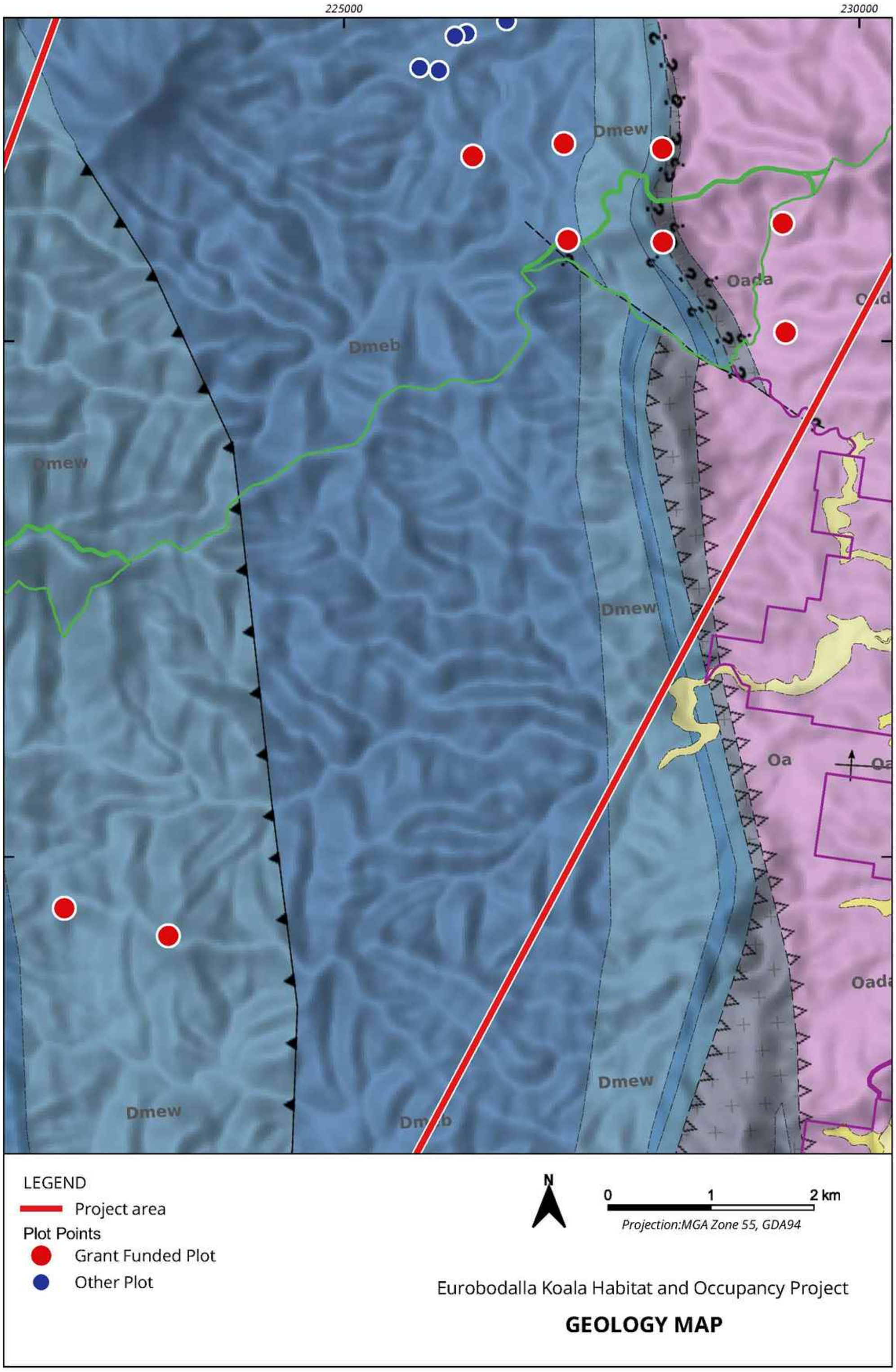
The Wamban and Nerrigundah nodes are over zones *Oada* (sandstone-dominated/Lachlan Supergroup) and *Q* (Quartanery Alluvials).

The surveyed plots are near the fault line between *Dmeb* and *Oada*, with a couple actually on the fault line. The latter explains the observed presence of pink colouring and quartz at some plots.

Plots GMSF1 and GMSF2 also have shale.

As a general rule, the geological pattern of the South Coast hinterland is "Late Ordovician quartz-rich flysch with tight to isoclinal meridional folding – axial plane cleavage not well developed" [Bendethera Report, op cit].

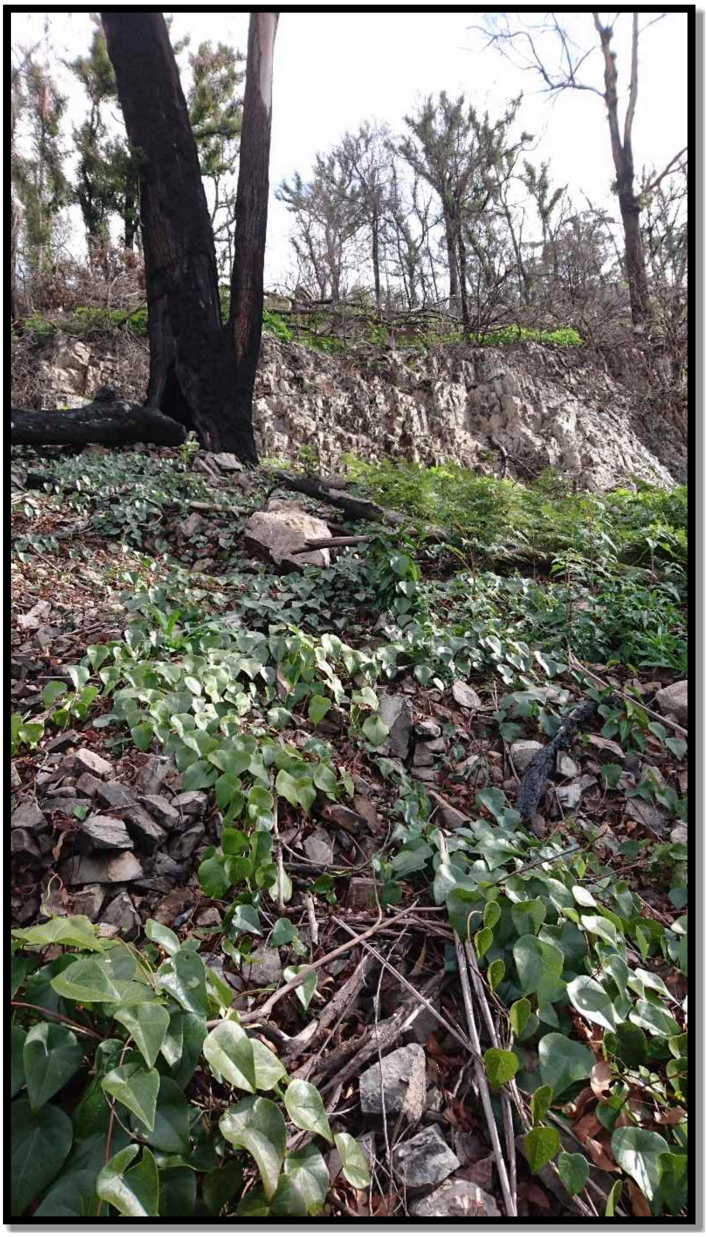
Hammond's [op cit] summary is as follows:
Ordovician sediments, tightly folded and eroded during the Silurian period, overlain by rocks from the Devonian age.
Mountain-building and erosion during the Carboniferous period.
Volcanic intrusions during the Tertiary period.
Alluvial deposits during the Quartanery period.


225000
230000
6010000
6005000
Dmew
Dmeb
Oada
Oa
LEGEND
Project area
Plot Points
Grant Funded Plot
Other Plot
N
0
1
2 km
Projection:MGA Zone 55, GDA94
Eurobodalla Koala Habitat and Occupancy Project
GEOLOGY MAP

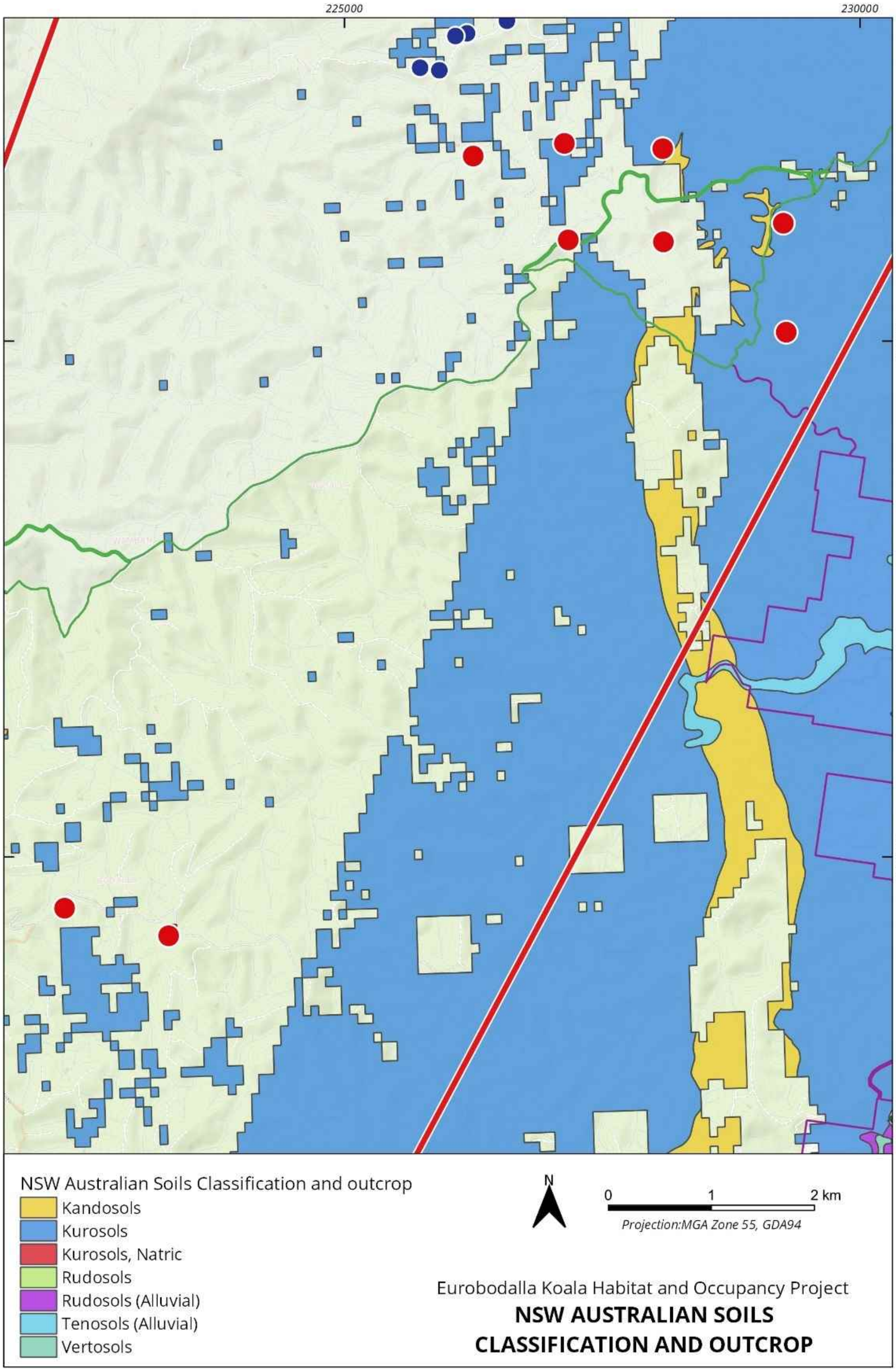
Descriptors for the codes on this map, plus a set of references and links to other information are at [https://eurokoalas.files.wordpress.com/2021/01/geology-references-and-links-zip.zip].

For example, the Clarke-Connors Ranges study (Qld) remarks: “Soils from the granitic rocks tend to be of low fertility. More fertile soils are derived from a few restricted areas of basalt.”

Rocky Ground near Plot GDNP2



Soil



225000
230000
6010000
6005000
NSW Australian Soils Classification and outcrop
Kandosols
Kurosols
Kurosols, Natric
Rudosols
Rudosols (Alluvial)
Tenosols (Alluvial)
Vertosols
N
0
1
2 km
Projection:MGA Zone 55, GDA94
Eurobodalla Koala Habitat and Occupancy Project
NSW AUSTRALIAN SOILS CLASSIFICATION AND OUTCROP

Braithwaite (1983) suggests the best koala habitat is on high-nutrient soils.

The Australian Soil Classification map shows the Wamban-Nerrigundah polygon sits over Kurosols (eastern side and alluvial nodes) and Rudosols (the larger central and western section).

- Kurosols are described as having strong texture contrast between the surface (A) horizons and the clay subsoil (B) horizons. The subsoil is strongly acid, ie pH is 5.4 or less in water, and non-sodic (at least in the upper horizons).
- Rudosols are described as usually coarse textured material with a very low clay content and minimal organic matter accumulation at the surface. Strongly acid. Low water holding capacity due to the coarse texture, abundant stones and shallow depth.

There are smaller expanses of Kandasols in the general area, such as the one not too far from Plot GMSF2.

- Kandosols are described as red, yellow and grey massive earths. They generally have a sandy-to-loamy surface soil, grading to porous sandy-clay subsoils with low fertility and poor water-holding capacity.

Our plot surveys usually record soils as "Sandy Loam" (rarely "Loam") at "Some Depth" (rarely "Skeletal").

Soil samples were taken at Plots GDNP2, GDNP4, GMSF1 and EMDSF1, each at about 7cm depth, and sent to the Australian Precision Ag Laboratory (APAL) for analysis. The main aim was to compare these with the samples analysed at Bendethera in 2013, especially to see if the 2019/20 hot wildfire had impacted on content and nutrients.

Remarks in the "*Life in a Southern Forest*" online publication were noted, eg
"After the fire, we worried about the effect on the soil. Would the chemical balance be all wrong? Would there be a loss of key nutrients? And what about the biota? The early plant growth gave us hope. The mushrooms provided further encouragement. And now that so many insects are emerging, ready to breed, we are confident that all will be well. The forest will continue to rebuild. It is already off to a very good start."
https://southernforestlife.net/happenings/2020/9/12/healthy-soil-life
and
"Soil minerals after fire
Fire has a fertilising effect. Minerals such as potassium, calcium, magnesium and boron are ash-derived and highly soluble. Luckily we had about 20mm rain within days of the fire, and nearly 200mm by the end of February. The *Xanthorrhoea* took advantage of the boon. Their roots will have absorbed these nutrients, fuelling the first flush of growth and also building a store of minerals in the stem for use in future leaf production – and in flowering!
The older leaves are progressively dying as they are replaced by the new growth. This is normal. Nutrients from the dead leaves have been returned to the plant while the dry,

brown leaves contribute to the leaf litter surrounding the crowns. Minerals such as sodium and potassium are quickly leached into the soil. Others, such as magnesium, calcium and boron tend to be retained – until burnt in the next fire!

Why do they grow in this one patch? I still do not have an answer. I suspect soil type. An exposed rocky cliff nearby suggests that the underlying rock may be rhyolite, an igneous rock formed from larva. I think. Perhaps this distinguishes the soil from the surrounding sedimentary sand. Maybe.

Drainage may also be involved. The site is higher than the surrounds. But this fails to account for the absence of grass trees on forested ridges nearby.

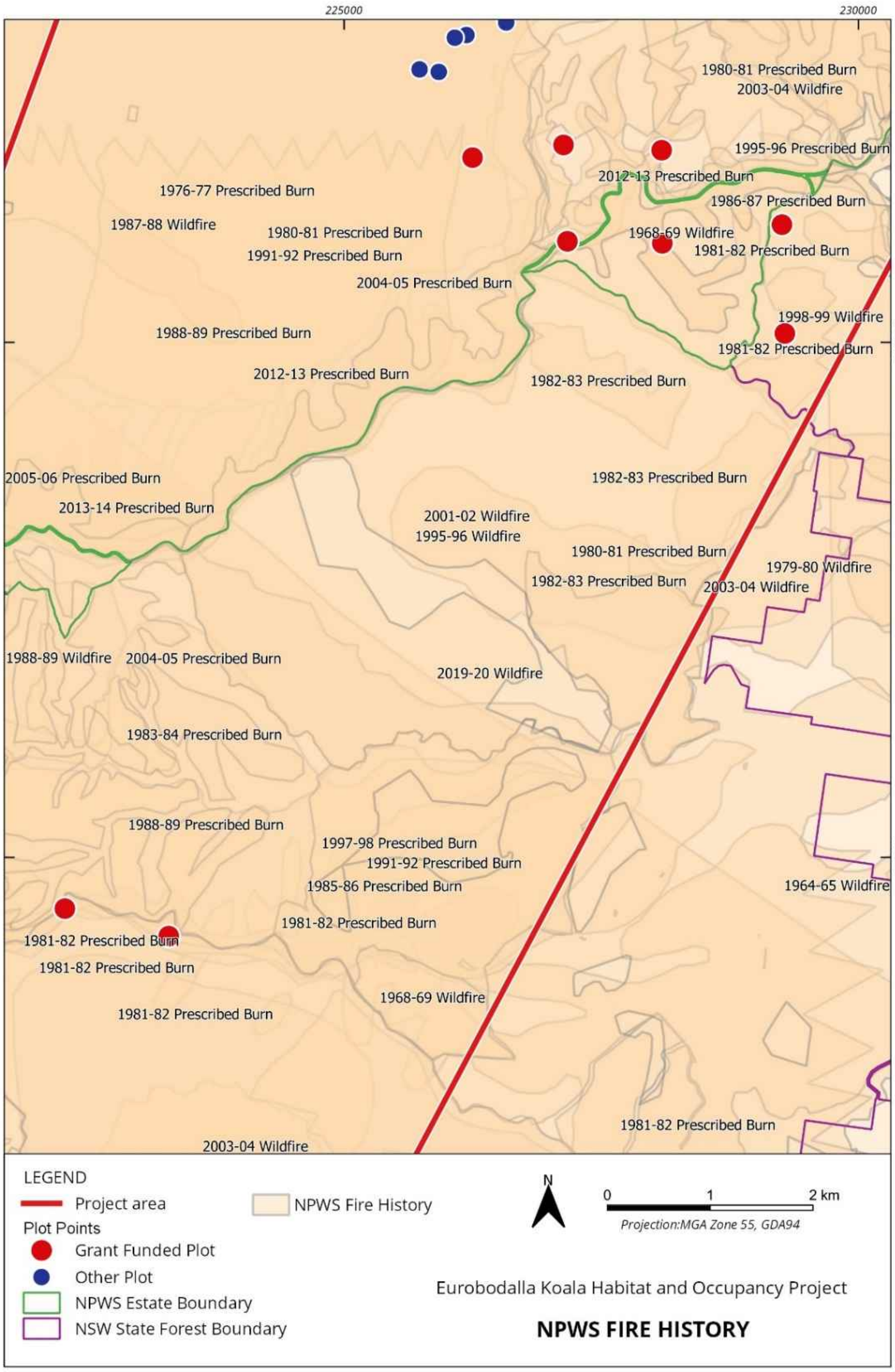
Maybe it's also historical. *Xanthorrhoea* grow very slowly and they live a long time. Perhaps past land use and fire patterns have left their mark."

- *From Life in a Southern Forest, 18th August 2020*

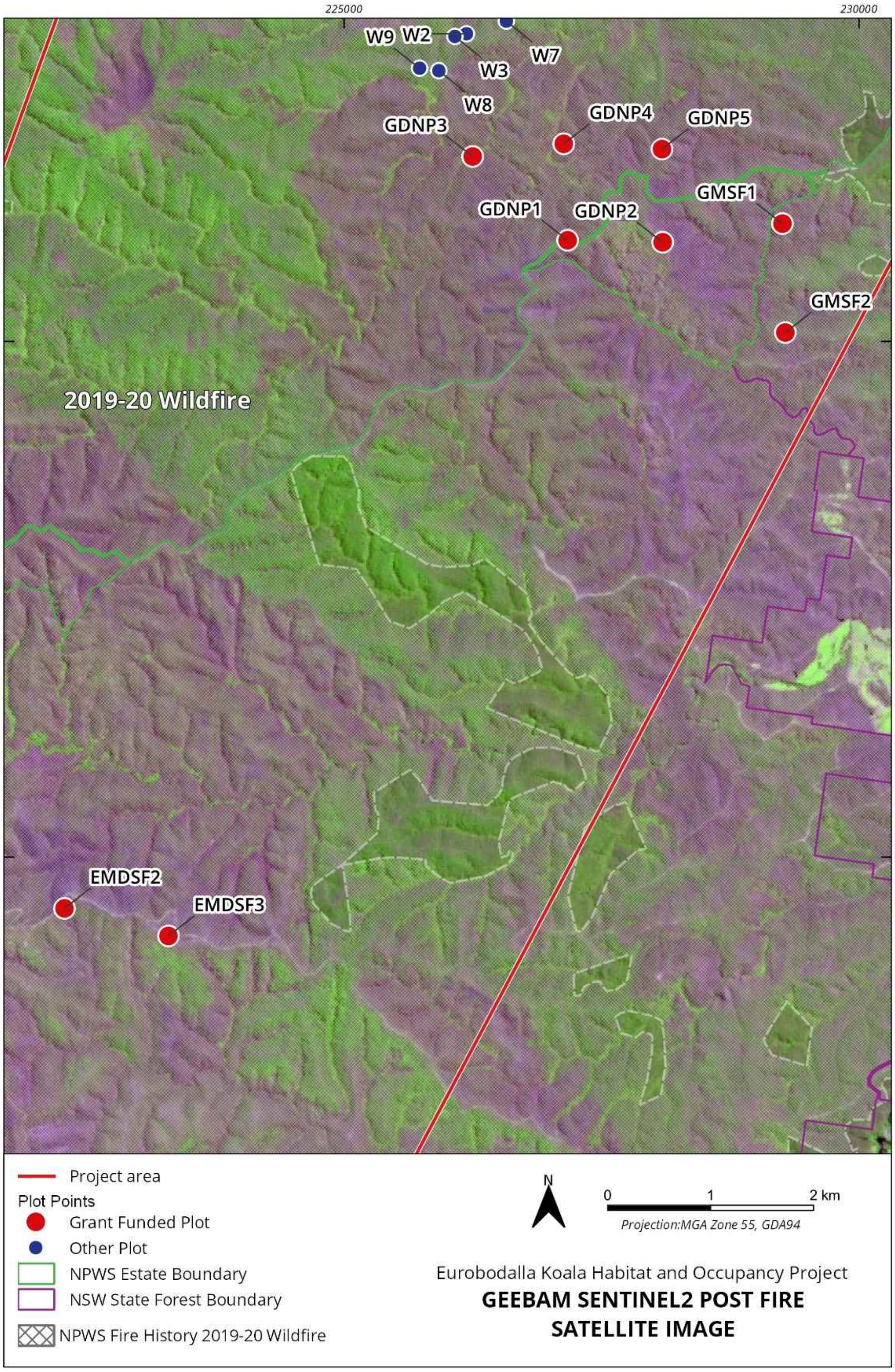
Soil on EMDSF Plot

FIRE

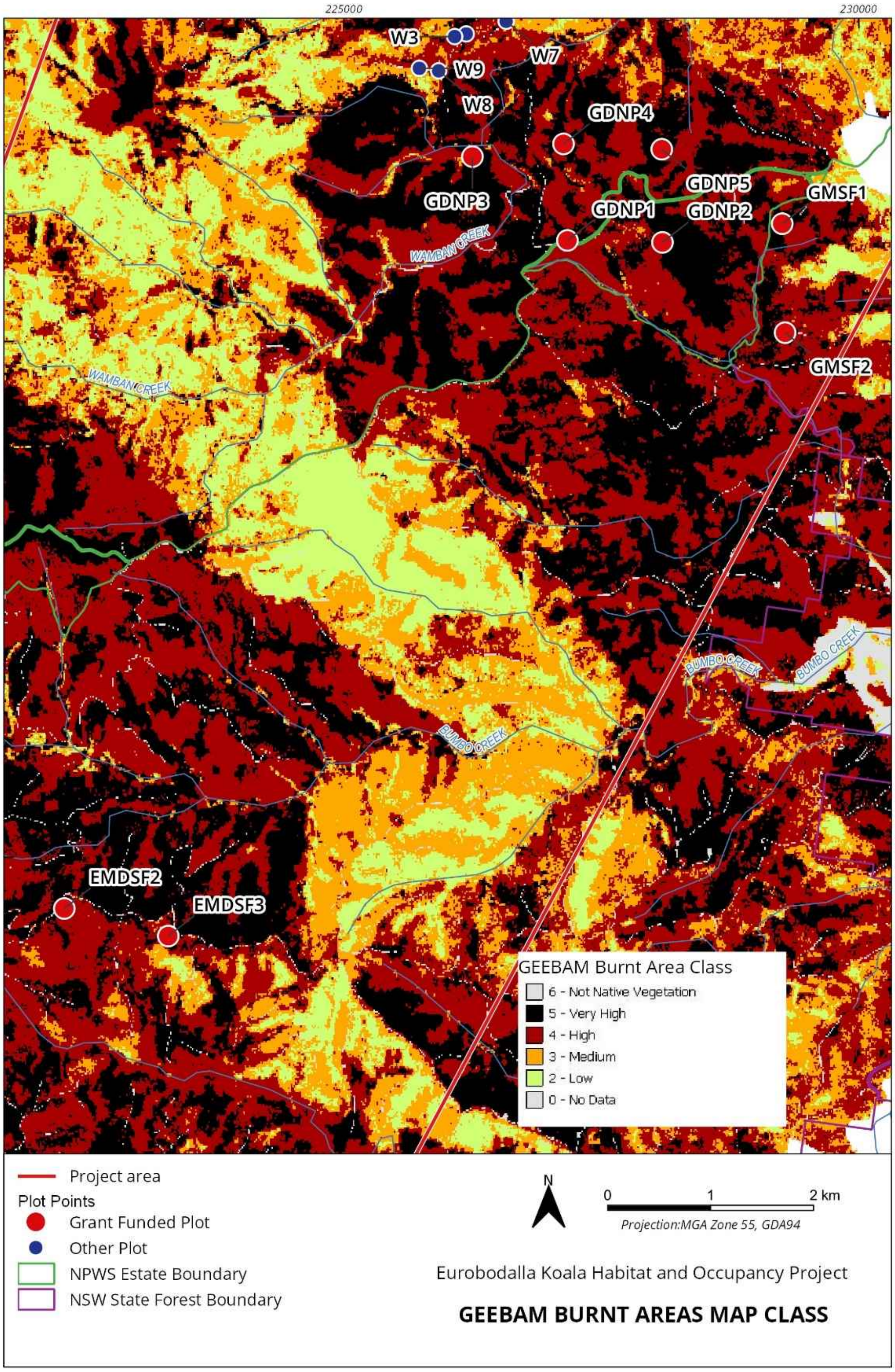
Fire History Map



Satellite Image of 2019-2020 Wildfire

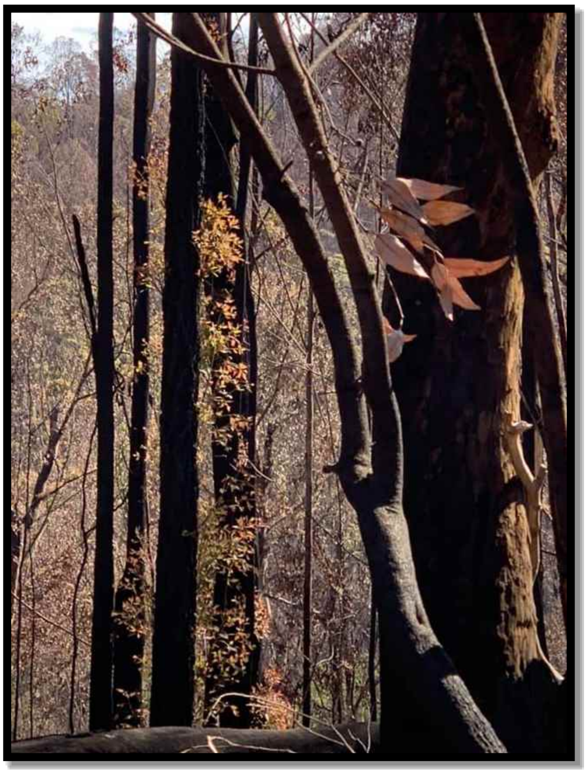


Intensity of 2019-2020 Burn



While awaiting post-wildfire access to the National Park and State Forests, our researchers attempted to monitor fire impact and early recovery through local landholder observations and photographs, obtained drone footage at a point on Little Sugarloaf Road midway across the patch, and undertook desktop research of scholarly articles.

Red Ironbark and Spotted Gum at Jingara Farm, Mogendoura 3.5 months after the fire – photo Michelle Scobie



The collection of local images was accompanied by a compilation of personal comments from landholders and project volunteers observing the fire impact on habitat.

The impression gained from these preliminary observations was that it took about three months for epicormic regrowth to establish itself and this would be a critical period for koalas seeking browse if they had survived the fires. Rough barked eucalypts such as Stringybarks and Ironbarks appeared to resprout first, with smooth-barked trees like Red Gums resprouting later. At a Buckenbowra/Runnyford private property surveyed six months post-fire the landholder showed Angophora floribunda that had been the first species to fully recover (including crowns).

<u>Drone Image Analysis</u>
On 8th May 2020, the WIRES-funded *Little Ripper* drone obtained 27 still images and two videos from a position on Little Sugarloaf Road halfway between the eastern and western boundaries of our mapped research polygon. The coordinates were approximately

149deg55minsE and 36deg02minsS; or UTM 55 H approximately 0764226metresE and 6007520metresS.

The images and videos are at the following links:

https://eurokoalas.files.wordpress.com/2021/01/drone-still-images-set-1-of-3-1.zip

https://eurokoalas.files.wordpress.com/2021/01/drone-still-images-set-2-of-3.zip

https://eurokoalas.files.wordpress.com/2021/01/drone-still-images-set-3-of-3.zip

https://eurokoalas.files.wordpress.com/2021/01/drone-video-1-of-2.zip

https://eurokoalas.files.wordpress.com/2021/02/drone-video-2-of-2.zip

These images demonstrate the state of the forest at relatively close scale after it had experienced ***approximately four months of post-fire recovery***.

Clear views were obtained above the canopy and at lower level where soil, ash, regenerating undergrowth such as cycads, burnt logs and the trunks of standing trees were visible. No water was visible.

It was possible to enter many of the items in the ground-truthing datasheets by using these images as a virtual plot survey, however precise identification of every burnt eucalypt species was impossible.

The variable impact of the fire was apparent. Some patches, both in a gully and on the side of a slope, appeared to have no damage to canopy and possibly elsewhere, while adjacent to these there was a patch where the fire had obviously burnt fiercely at all levels. One central patch (about half of the close-scale view) was thinly vegetated, prompting speculation about whether this was a pre-existing condition or a fire impact. The road at the drone-launch site appeared to have diminished the impact of the fire in sections on one side.

Strong epicormic reshooting had already occurred on this date, amongst smooth-barked trees (eg identifiable Spotted Gum and one or two others of unclear species) and those with blackened trunks (probably Stringybarks).

Recovery Time

In his publication "The Great Koala Scam" (connorcourt PUBLISHING, 2020) provocative minority-view koala historian Vic Jurskis argues that koalas "irrupt" when forests are not managed properly (ie cool burnt every year) hence becoming overgrown and eventually suffering catastrophic wildfire. His remarks don't provide clear information on how long it takes a forest to recover from fire to the point of koala "irruption" but combining Vic's thoughts with indigenous cultural burning timeframes a period of 3 to 10 years might be postulated. This topic will be revisited in "CONCLUSIONS AND RECOMMENDATIONS - Time, Natural Revival and Reintroduction" below.

Deua National Park, Plot GDNP4 – August 2020, 8 months after fire

Desktop Research

Facebook posts by members of the Eurobodalla Koala Project's network were often instructive, such as this one on post-fire bush recovery, at:
https://www.facebook.com/100001814059073/posts/4382414725162286/?sfnsn=mo&extid=8qyyL9x5N7DCLlSX
and this one on Xanthorrhoea recovery, at:
https://www.facebook.com/1977232972564122/posts/2804306853190059/?sfnsn=mo

The **Sustainable Farms (ANU) Webinar of 22nd May 2020** was instructive.
The two main presenters were Professor David Lindenmayer (ANU) and Mason Crane (Senior Research & Extension Officer, Sustainable Farms ANU).
The topic was fire. A selection from the notes is as follows.

Prof Lindenmayer summarized recent research. Items of relevance to our project included:

- The importance of clarity in definitions, ie intensity, severity, fire regime, wildfire, hazard reduction, backburn, blackout burn, regeneration burn, cultural burn.
- Not all definitions of fire are independent of each other.
- In forest ecology, condition prior to fire has a big impact on recovery after fire.
- There is faster and more vigorous recovery if more biomass and older trees are there beforehand.
- Fire in a young forest (eg a forest that's been logged and then regenerated) is very different in its effects than an older one – canopy fire is worse until trees are from 40 to 100 years old (ie well after they tend to be logged).
- In farmland fire dynamics, windspeeds are critical.
- For fire management farms need good vegetation cover planning (where; condition prior to fire) and management after the fire.

Mason Crane summarized research into the impacts of fire on wildlife in various locations he has worked as part of a major project, and gave advice on farm management:

Jervis Bay (coastal heathland)

Birds

- The majority of species and bird assemblage in most vegetation types recovered within two years.
- Recovery after a single fire did not reflect the long-term effects of multiple fires.

Small mammals

- No burnt sites were totally devoid.
- There was no evidence of post-fire succession from one species to another, in heathland.
- Small mammals did worse in burnt sites.
- Long-nosed Bandicoot responded well to either fire or fox baiting or both, though numbers dropped off even though baiting continued.
- Ringtail possum numbers dramatically declined.
- There was a spike on Greater Glider sightings after the fire but numbers quickly crashed and the species became extinct after 4 years.

Wallabies and Kangaroos

- Responded well to fire.

Owls

- Very high numbers after fires, eg Powerful Owl, Sooty Owl.

Fire, fox baiting, isolation and interspecies relationships are complex. It's "a complexity of simple relationships".

Post-fire recovery in the Central Highlands of Victoria (eg Marysville, 2009 etc)

- Some birds enjoyed the opening up of forests by fire and numbers exploded, but others didn't.
- Small mammals decreased, except house mice.
- The big impact on wildlife was the loss of hollow trees.
- Even in low severity fires, after the fire any dead "stag tree" burnt.
- Logging cuts trees out too early for canopy and stag tree species.
- Riparian areas and rocky outcrops are important refuge during and after fire.
- Most species' populations recover from local survivors.
- Fire exacerbates the loss of hollow trees and connectivity.
- In road maintenance there's a delicate balance needed when it comes to post-fire transport safety works. Often roadsides have the biggest hollow trees.
- Habitat fragmentation makes it very hard for species to revive once they "wink out".

Comments prompted by webinar participants' questions:

RFS observation

- "Ladder fuels" like vines can lead flames up to canopy. *(The research and modelling say this is especially when forests are very young.)*
- More open understory seems to reduce fire intensity.

Species do transfer.

- For example there are now more Gang Gangs in some areas.
- The amount of hunting birds is greater with the loss of lower vegetation.
- At Tumbarumba, predators moved in such as Barking Owls hunting Squirrel Gliders.

Invertebrates

- The understanding of what invertebrates do is almost completely unknown.
- Jewel Beatles can detect smoke through their limbs, turn up quickly and abundantly for a few days then they're gone.

A reference list from this Webinar is at [https://eurokoalas.files.wordpress.com/2021/02/reference-list-from-sustainable-farms-webinar.docx].

SUSTAINABLE FARMS WEBSITE
http://www.sustainablefarms.org.au/

A substantial reference list was compiled on fire generally, for example that of **Bentley and Penman**:

https://www.publish.csiro.au/wf/wf16150
Wildfires are a natural disturbance in many ecosystems, creating challenges for land management agencies who need to simultaneously reduce risk to people and

maintain ecological values. Here we use the PHOENIX RapidFire fire behaviour simulator to compare fuel treatment strategies that meet the twin objectives of reducing wildfire risk to human settlements and a fire sensitive endangered species, the koala (*Phascolarctos cinereus*) in south-eastern Australia. The local koala population is in decline and a conservation management plan is being prepared to exclude wildfire for a 10-year period to assist with population recovery. Twelve scenarios developed by the land management agencies were compared using four indicators: wildfire size; burn probability; impact from exposure to fire; and treatment cost. Compared with the current risk setting, three treatment scenarios were found to reduce wildfire size and burn probability concurrently to both people and koalas. These strategies worked by increasing the landscape area treated, which came with increased financial cost. However, the impact from exposure to fire for both property and koala habitat remains high. Additional complementary strategies beyond landscape fuel reductions are needed to reduce impact from exposure in the event of a wildfire. (Abstract)

Another is the Commonwealth Government report published in ***Australian Journal of Zoology*** 43: 59-68.

http://www.environment.gov.au/biodiversity/threatened/species/pubs/koala.pdf

Fires and Drought

Bushfires can cause substantial Koala mortalities, destroy and fragment Koala habitat and reduce food availability for the surviving population (ANZECC 1998; Melzer et al. 2000). Inappropriate fire regimes can also change the plant composition of Koala habitat, by depleting some plant species and favouring other species that are fire tolerant (Queensland EPA 2005; NPWS 2003). The capacity for Koalas to repopulate fire-affected habitat depends on the intensity of the fire, the extent of habitat fragmentation, the proximity of other Koala populations, and the presence of other threats (NPWS 2003). Severe, prolonged drought can also cause significant Koala mortalities and can result in the acute reduction of local or regional Koala populations (ANZECC 1998; Gordon et al. 1988). However, Koala populations can recover from droughts and recolonise former habitat (Martin and Handasyde 1999). Koalas have been observed to move away from drier areas to areas along rivers and creeks during droughts, and the presence of nearby refuge habitat influences the capacity for Koalas to survive prolonged drought (NPWS 2003).

One of the best indicators of the timing and the progressive nature of southern forest recovery was the monthly online publication ***Life in a Southern Forest – biodiversity & ecology in the Australian bush*** op cit, containing excellent photographs and some accompanying commentary: https://southernforestlife.net/

An example is in the April 2020 edition prompting our observation *"After a 5th January fire, it now (17th April) seems epicormic growth is wilting and trees are beginning to recover higher up towards their canopies?"*

There was heavy media coverage of the impact of fire on koalas, eg ***The Guardian*** "Koala factcheck: have the Australian bushfires put survival of the species at stake?" https://www.theguardian.com/environment/2019/nov/26/koala-factcheck-australian-bushfires-survival-species-at-stake

Of high significance to our project's emphasis on potential habitat and revival was the ***Canberra Times*** article of 24th September **1968** (op cit) detailing **diminution of the Wamban koala population** during that year's fire and the previous devastating fire of **1952**: https://trove.nla.gov.au/newspaper/article/131672798?searchTerm=%20koalas%20Wamban&searchLimits=

Miscellaneous information sources were accessed.

In April 2020 "**The Open Road**" (NRMA newsletter) published an informative article about resprouting, interviewing fire specialist Dr Tina Bell. Dr Bell's CRC link is https://www.bnhcrc.com.au/people/tbell.

The ABC program "**Gardening Australia**" aired an excellent piece with Costa in the Blue Mountains touching upon loss of soil nutrients, seedling regrowth and epicormic shoots. Rebounding native ground orchids are discussed at https://www.bbc.com/news/science-environment-52204434 and https://www.google.com/search?q=native+ground+orchids+of+south+east+nsw&rlz=1C1GCEA_enAU891AU891&oq=native+ground+orchids+of+south+east+nsw&aqs=chrome..69i57.15747j0j1&sourceid=chrome&ie=UTF-8.

ABC Radio broadcast a program called "Post-Fire Ecological Stocktake" at https://www.abc.net.au/radionational/programs/saturdayextra/post-fire-ecological-stocktake/12050408?fbclid=IwAR1LHFo8qN0dRo8J7rVf5TTPR4VAznm1d29PsUeSMYgIyZ04sPB9puNSTUY

Romane Cristescu, specialist in **Detection Dogs for Conservation** posted regularly on Facebook about what she was finding after fires, eg https://www.facebook.com/100001814059073/posts/3730626023674496/?sfnsn=mo

The **Institute of Foresters Australia** conducted a webinar on recovery after damaging events. Unfortunately this item appears now removed from the website, but contact for advice might be obtained through https://www.forestry.org.au/Forestry/Events/

Craig Dunne, **Forestry Corporation NSW ecologist** at Batemans Bay reported on 27th April that: “1) A significant microbat colony at Bimbimbie mine (hit hard by fires near Mogo), is still alive and doing well. 2) My night surveys in light-moderate burnt areas have detected a greater glider, powerful owl and Masked owl. As well as various other common nocturnal species such as sugar gliders, brushtails, Boobooks and owlet nightjars.”

The following link showed Eucalyptus globoidea resprouting:
https://www.google.com/search?tbm=isch&sxsrf=ACYBGNQRPCV9w_SxSDalpSBDWapSa3KyVA:1579806357638&q=eucalyptus+globoidea&chips=q:eucalyptus+globoidea,online_chips:white+stringybark+eucalyptus&usg=AI4_-kTvwsbNnRRBVvQgtFJTt7JhjbY_fQ&sa=X&ved=0ahUKEwiT8oqmtZrnAhXDIbcAHSR1CiwQ4lYILCgB&biw=1336&bih=546&dpr=1#imgrc=W7BEWVXroEfrRM:

Significant literature on fire and koala habitat was comprehensively summarised by our volunteer Jasmin Bourne.
A selection from Jasmin’s summary is as follows.

Koalas and climate change, and anthropogenic impacts

Koalas adversely affected by…

Climate change now recognised as major and exacerbating threat to Australia’s wildlife – increasing hostile environment with rising temps and lowered rainfall in fragmented habitats – drought has a huge impact (80% reduction in koala numbers during drought in western QLD and limits koalas to riparian habitats = lack of leaf moisture massive problem) (Lunney et al. 2014).

Lunney et al. (2014)

- climate change impacts are:
  - increased drought
  - heatwaves
  - decreased leaf moisture
  - decreased leaf nutrition
- main findings – marked shrinkage of koala distribution across Eden region – from multiple threats including direct human land use, and climate/environmental change – particularly drought and rising temps (*also in SCoast section)
  - helping fauna on a local scale adapt to these changes of utmost importance

- Kingsford and Watson (2011) – highlighted the distinctions between direct (fires, storms, drought, extreme rainfall) and chronic (gradual increases in mean temp, decreases in seasonal rainfall ie climate change) impacts

This is supported by Black et al. (2014)

- koala mortality from severe drought and heatwaves has been observed at between 63% to 80% in arid and semi-arid environments

<u>Black et al. (2014)</u>

- past records (millenia) show that progressive aridification (such as unpredictable climatic conditions and increased seasonality) has caused changes in the species diversity and geographic range of koalas across the Australian continent
- as such, predicted increases in extreme climatic events (hotter and drier overall) will contract the geographic range of the koala eastwards and southwards, where they are met with increasing pressures from urbanisation
  - modelling has revealed that in five key eucalypt species climate change will cause variable but increasing fragmentation between koalas and their preferred food species
- bushfires cause not only direct mortality but indirectly through further habitat loss, fragmentation and other associated changes (composition of vegetation) for surviving populations
- koala carrying capacity not just dictated by the presence of koala feed trees, but the soil chemistry (high nutrient levels), water foliar content,
  - climate change may affect available palatable foliage and nutritional content of leaves, as eucs grown under elevated CO_2 levels were found to produce anti-herbivore compounds in higher concentrations, but nitrogen levels decreased (Lawler et al. 1996)
- historically, phascolarctids (specialist folivores) are very sensitive to changes in climate, causing the extinction of koalas from large areas of Australian continent in the Pleistocene
  - this sensitivity, combined with increasing modern and anthropogenic pressures further contracting their natural range may contribute to the extinction of localised populations

<u>Matthews et al (2007)</u>

- Lunney et al (2007) (in Matthews)
  - both frequent prescribed fires and less frequent but high intensity wildfires are implicated in a heightened risk of extinction for Port Stephens koala pop's
    - major conclusion from this was that fire regimes in forest fragments will have a significant impact on long-term survival of P.S. koala populations

<u>Narayan (2019)</u>

- measures koala physiological stress levels by analysing fresh faecal samples for 'faecal glucocorticoid (or cortisol) metabolites (FGMs) enzyme-immunoassay (EIA)' with a healthy unstressed control population
- found that the biggest impact on increased FGMs was loss of prime eucalypt habitat (land clearing), with bushfire related factors such as dehydration, burns injury and flat demeanour following closely
- surmises that stress from anthropogenic processes/impacts has the tendency to increase the physiological stress in wild koala populations

   - further surmises that koalas with increased FGMs due to these factors are potentially more likely to be involved in increased incidences of more direct and proximate stressors such as vehicle collisions or dog attacks
- management implication is that as we expand our land and road developments there will be an increased need for ecological monitoring and conservation management actions, including policy, for koala populations

Koalas on the Far South Coast

The Far South Coast has historically been habituated by koalas, although these populations have undergone major retractions in range and distribution since European settlement. Intensive logging, agriculture and urban development have all impacted on the habitat along the coastal area, with sharp declines in koala presence since the chipping industry was launched in Eden (Lunney et al. 2014). Ongoing drought, disease and dog attacks have exacerbated these impacts (Lunney et al. 2004).

Wildfires similar in intensity and severity to the 2019/2020 events on the South Coast occurred in Port Stevens (1993/4?). In Port Stevens, high intensity crown fire in patches resulted in complete canopy loss, large areas of canopy scorch, and patches of lower/moderate fire intensity that left some crown remaining, plus small unburnt patches. This was followed by rain that triggered epicormic growth (Lunney et al. 2007).

Lunney et al. 2014

- studies on koalas in the Eden region since 1986 to build a reliable picture of the fluctuations of the koala population in Eden
- significant koala populations known in the Eden region at the end of the 19th Century, but European settlement, intensive logging, agriculture and urban development have all contributed to widespread declines/severe protraction of range to just a few isolated populations in the hillside forests behind Bega, Towamba, Bermagui (1970s onward – logging, chipping industry launched)
- main findings – marked shrinkage of koala distribution across Eden region – from multiple threats including direct human land use, and climate/environmental change – particularly drought and rising temps
   - helping fauna on a local scale adapt to these changes of utmost importance
- Decreases in Foliage Projection Cover (clearing, drought)
   - FPC – foliage projected cover
      - veg-cover data, time series for woody veg FPC was generated to represent the no tree cover -> dense forest and represents the vegetation change over time – this includes all veg changes including clearing, logging, foliage loss/gain due to drought/rain
- location (southern, coastal) does not provide immunity to climate change issues
- This study carries out a new community survey to detail current distribution, and attempts to establish not only how known multiple threats have contributed to declines, but the exacerbating role climate change may be playing
   - modelled current/past distributions against:

    - changes in human pop
    - fire
    - foliage projective cover
    - climatic variables (esp. temp and rainfall)
  - to distinguish between multiple causes of decline between now and 1975

Matthews et al (2007)

- Port Stephens fires seem to be fairly similar to ours in Deua in terms of intensity and severity, high intensity crown fire in patches resulting in complete canopy loss, large areas of canopy scorch, and patches of lower/moderate fire intensity that left some crown remaining, plus small unburnt patches. Followed by rain that triggered epicormic growth

Other threats – drought, disease and predation by dogs exacerbate populations declines (Lunney et al. 2004)

2019/2020 bushfires/major bushfire events

Chia et al. (2015)

- that wildfire is a driver of landscape heterogeneity, which is heavily influenced by environmental factors that mediate the burn regime/that affect the variation in fire severity burn patterns are also influencing resource availability – these factors include topography, climate, vegetation through soil nutrients, water availability – and in turn influences the distribution of biota
- Wildfire as a driver of landscape heterogeneity and its impact on arboreal mammals (limited knowledge but suggests they are particularly vulnerable)

Bradstock et al 2002

- fire in Australia can cause large losses of wildlife through mortality, and this threatens the viability of isolated populations and their long-term survival in fragmented habitats, especially if those species are less mobile or slow to reproduce – and this is when rehabilitated and released animals can become very important

Lunney et al. 2004)

- enhancing recovery of koala populations depleted by fire is of particular importance as fragmented habitat causes isolated populations that are highly subject to localised extinction events ie the whole small patch burning, as well as increased extinction risk if recovery time is too slow
- Fire intensity/wildfire similar to Deua – 3 fires:
  - high intensity crown wildfires with low-mod patches of only scorched canopy.
  - hazard reduction burn covering 50ha
  - low-intensity wildfires with crown scorching
  - **regen of epicormic shoots within three months – koalas seen within the epicormic growth**

- HOWEVER – wildlife rescuers going into the fire ground immediately post-fire observed a lot of perished animals and very few unburnt – leading to the assumption that many of the animals in the area would have been killed.
- carrying capacity due to defoliation of habitat would have been immediately reduced for surviving animals (food and shelter) and therefore immediately returning rehabilitated animals to the forest area post-fire may have led to increased competition
- however, this effect is surmised to be greatly reduced just a few months in due to epicormic growth and the knowledge that koalas happily utilise this

How koalas use burnt landscapes/Koala response to fire

Lunney et al. 2004

- Study looking at long-term survival and reproduction rate of koalas fragmented forest in Port Stevens – compared a group of injured, rehabilitated and released koalas (*n* = 16) with uninjured koalas (*n* = 23)
  - 3 years of monitoring following release
  - **ultimately found no difference in rehabilitated vs uninjured koala survival rate**
  - **reproduction in the two breeding seasons after fires did not significantly differ between groups**
    - however – leading cause of mortality for both groups was dog attack
  - very small study but still gives an idea of the potential for koala survival post-fire
- knowledge gap identified around ongoing monitoring of rehabilitated animals after release
  - too expensive or too difficult
  - value not realised
  - if it is carried out tends to focus only on short term survival of individuals and doesn't compare with existing populations – previous studies have shown that koalas can indeed establish successfully after release, but leaves it unclear as to how successful that establishment is long-term enough for breeding and reintegration with wild populations
- however, this effect (increased competition) is surmised to be greatly reduced just a few months "The common vegetation communities relevant to koalas are melaleuca swamp forest, dominated by broad-leafed paperbark *Melaleuca quinquenervia* and swamp mahogany *Eucalyptus robusta*, and forest associations of blackbutt *Eucalyptus pilularis*, smoothbarked apple *Angophora costata*, old man banksia *Banksia serrata* and red bloodwood *Corymbia gummifera*. Associations of drooping red *gum Eucalyptus parramattensis* also feature in low open forests. Wet and dry heath communities, grasslands and sedges are also present. *Eucalyptus robusta* and *Eucalyptus parramattensis* have been identified as the two most preferred tree species of koalas in the Port Stephens area (Phillips et al., 2000)."
- Fire intensity/wildfire similar to Deua – 3 fires:
  - high intensity crown wildfires with low-mod patches of only scorched canopy.
  - hazard reduction burn covering 50ha
  - low-intensity wildfires with crown scorching

- **regen of epicormic shoots within three months – koalas seen within the epicormic growth**

- Chia et al. 2015
  - low observation numbers (possibly due to survey being done after terrible drought) but still:
    - most observed at unburnt sites
    - less in sites with a burnt understory (check wording)
    - and less again in severely burnt sites
  - Fire regime
    - **severity was found to have the greatest influence on abundance of arboreal mammals**
    - no significant difference between sites with a burnt understory and unburnt sites, or sites with large trees (except Greater Gliders were positively associated with sites that contained more large trees)
  - Isolation
    - abundance of arboreal mammals was influenced by the isolation of unburnt sites within severely burnt areas
    - when the unburned and understory-only burned areas was less isolated across the wildfire boundary area, mammal abundance increased, sites with more isolated unburnt/understory-only burnt patches supported fewer arboreal mammals
  - Three key findings:
    - abundance of arboreal mammals was influenced by topography ie higher abundance in gullies than slopes
    - Fire severity matters - 2.5 yeas on affecting abundance of arboreal mammals, with severely burnt forest supporting less than unburnt.
    - A study 3.5 years on showed that arboreal mammal abundance in severely burnt forests was still influenced by landscape context ie severely burnt forests surrounded by unburnt and understory-only burnt patches supported more arboreal mammals 3.5 years on than those that were more isolated from similar patches (separate study)

Matthews et al (2007)

- Authors concluded that:
  - fire response will be site specific
  - life cycle and influencing habitat factors needs to be understood
  - more needs to be known about the response of koalas to fire incl temporal and environmental variables affecting occupancy
- Extensive fires in the north coast of NSW in 1993/94 prompted first ever long term study to examine the effects of wildfire on a koala population
- SUPPORTING EVIDENCE from other papers:
  - Reed and Lunney 1900 - fire has played a part in the current dist'n of NSW koalas
  - Curtin et al 2002 - koalas present 15 months after 60% of site burned, presumed gullies provided refugia
  - Lunney et al 2002 - koala dispersal may be affected by major fires acting as barriers

- In Port Stephens (Lunney et al 2004) found that:
  - mortality high
    - BUT
      - no difference between rehabilitated/unburnt koalas (found in nearby forest) in survival/reprod rates
      - and reprod rates relatively high suggesting post-fire resources sufficient
- Dogs have a compounding effect
- Matthews et al (2007)
  - both frequent prescribed fires and less frequent but high intensity wildfires are implicated in a heightened risk of extinction for Port Stephens koala pop's
    - major conclusion from this was that fire regimes in forest fragments will have a significant impact on long-term survival of P.S. koala populations
- Findings:
  - Koala use of burnt trees high, with some exclusively and preferentially choosing burnt trees with regrowth
  - number of trees used by an individual koala/length of time in the study positively correlated – koalas don't often revisit previously visited trees!
- **Use of burnt forest**
  - koalas heavily used burnt forest and some exclusively fed on the new shoots suggesting that they provide enough nutrients for survival.
    - It has been suggested that the new shoots are in fact nutritionally superior to adult leaves (Moore et al 2004). Suggesting resource depletion by fire is a relatively short-lived effect.
    - However, unburnt patches were essential immediately after fire for sustaining pop'ns
    - including how quickly the burnt patches could be recolonised
  - unburnt patches essential in as a source population, and unburnt trees amongst the burnt
  - Injury post-fire is a problem as koalas attempt to move across the landscape
  - Results show that koalas can use burnt habitat as long as there is sufficient regrowth, meaning that injured and rehabilitated koalas removed from bushland post-fire can be returned confidently close to point of capture to maximise chance of reestablishment

<u>The habitat requirements of koalas</u>

- "The common vegetation communities relevant to koalas are melaleuca swamp forest, dominated by broad-leafed paperbark *Melaleuca quinquenervia* and swamp mahogany *Eucalyptus robusta*, and forest associations of blackbutt *Eucalyptus pilularis*, smoothbarked apple *Angophora costata*, old man banksia *Banksia serrata* and red bloodwood *Corymbia gummifera*. Associations of drooping red *gum Eucalyptus parramattensis* also feature in low open forests. Wet and dry heath communities, grasslands and sedges are also present. *Eucalyptus robusta* and *Eucalyptus parramattensis* have been identified as the two most preferred tree species of koalas in the Port Stephens area (Phillips et al., 2000)." – not edited (Lunney 2014??)

<u>Callaghan et al. (2015)</u>

- **Habitat resources** determine geographic range and population levels ie overall distribution and location of home ranges.
- At a home range level, the habitat resources determine food availability and quality, shelter and space for reproduction, survival and dispersal.
  - **Ultimately** the quality of the habitat is reflected in the overall fecundity, survival and population growth rates, and directly implicates survival vs extinction.
  - **Therefore** it is important to quantify and map species-specific habitat quality to better understand population dynamics and conservation requirements.
- Authors put forward that koala's reliance on euc's mean they are a limiting factor, but that should not assume that supplementary food tree species and those used for shelter are not also important factors

Matthews et al (2007)

- ***Koala ecology***
  - koalas more solitary when the landscape allows it ie low pop'n density and large home ranges
  - single use of trees may drive movement
  - appears to be routine as it was observed many times over the three years of the study
  - non-feed trees still important for day shelter and maintaining social hierarchies through non-contact scent marking
  - day time roost tree species often differed from nighttime feed tree ie the species in their diet (Ellis et al 2002a)
- prefer trees in the 51–70-cm diameter class and were not found in small (1-10cm) regenerating class
- research appears to show that koalas require structurally complex forests with large old trees for shelter and new growth for food (uneven-age trees) and as such removal of large trees for foresty etc will have a long-term impact on koala pop'ns even with a koala tree planting program in place
- Questions around tree use that has not been previously examined:
  - leaf quality and chemical composition vs landscape distribution ie how much habitat does a koala pop'n require and how do they utilise fragmented forest
  - do they utilise burnt trees? esp those subjected to hot crown fires

Factors affecting food quality/availability

Lunney et al. (2014)

- leaf nutrition affected by rising CO_2 concentrations – extent of impact not yet determined
- decreases in Foliage Projected Cover (FPC) from clearing and drought (Lunney et al. 2014)

Callaghan et al. (2015)

- **Substrate, tree size and foliar chemistry**
  - results counter-intuitive as koalas were found more prevalently on low fertility soils countering the hypothesis of soil fertility-tree nutrients. HOWEVER it is noted that may be due to areas of high soil fertility having been cleared for farmland, therefore pushing koalas to areas of lower soil fertility.

- Moore and Moore and Foley have proposed a potential link between koala tree use based on tree size, foliar nutrient content and plant secondary metabolites. This seems to be supported. 'nutritional leaf quality'
- Being able to map foliar chemical composition by proxy of tree species using remote sensing may help refine KHA mapping capabilities

- - Moore and Foley (2005) suggest that higher visitation frequency to Tasmanian Blue Gum *Eucalyptus globulus* and Manna Gum *Eucalyptus viminalis* on Phillip Island is due to the fact they contain more nitrogen and less plant secondary metabolites, and therefore foliar chemistry influences distribution

Preferences (seasonal/day/night)

Callaghan et al. (2015)

- Habitat quality for **Arboreal folivores** is largely determined by the availability and suitability of the key food and shelter resources - for koalas these are the key eucalypt species favoured for their nutritional/chemical composition/moisture (and therefore seasonal - see below) qualities
- **moisture/seasonality** - including subsoil moisture affecting moisture content in leaves during drought - evidence suggests that this is an important determining habitat quality factor for semi-arid QLD koalas

Matthews et al (2007)

- Males/females/breeding/non-breeding/with young all preferred different tree species
- seasonal use change - req more moisture in summer, more energy in winter
  - For example, the non-feed trees *A. costata* and *E. pilularis* were used more often in summer. These species were also two of the largest trees used in the study area, indicating that the preference for these species is to provide greater shelter during the hotter summer months.
- *Eucalyptus robusta* and *A. costata* were the species most frequently used by koalas
  - Male and female had different preferences:
    - Female - *E. robusta*, *M. quinquenervia*, *E. parramattensis*
    - Male - *C. gummifera*, *E. signata* and its hybrid *E. haemostoma/E. signata*, and *E. pilularis*.
  - Breeding and non-breeding females also had different preferences
- “Tree species preferences of koalas were determined by comparing trees available in plots with trees used within the same area. Koalas selected *A. costata*, *E. pilularis*, eucalypt complexes, *E. punctata*, *E. robusta* and *E. signata* and avoided *A. floribunda*, *Allocasuarina glauca*, *Banksia* sp., *E. eugenioides*, *E. parramattensis*, *E. piperita*, *E. tereticornis* and their hybrids and *Melaleuca* spp.”
- Day vs night use of trees –
  - known feed trees at night *E. robusta* and *E. parramattensis*.
  - day trees - *A. costata*, *E. signata* and *C. gummifera*.
- Seasonal use of trees varied:
    - hotter months - *A. costata*, *E. pilularis*, *E. signata*, *M. quinquenervia*, *E. parramattensis*, *E. punctata*, *A. floribunda* and *E. eugenioides/E. capitellata*
    - *cooler months – E. robusta*, *E. haemostoma/E. signata* and eucalypt complexes

Impact of landscape conditions

- Black et al (2014)
  - koala carrying capacity not just dictated by the presence of koala feed trees, but the soil chemistry (high nutrient levels), water foliar content,
    - climate change may affect available palatable foliage and nutritional content of leaves, as eucs grown under elevated CO_2 levels were found to produce anti-herbivore compounds in higher concentrations, but nitrogen levels decreased (Lawler et al. 1996)
  - historically, phascolarctids (specialist folivores) are very sensitive to changes in climate, causing the extinction of koalas from large areas of Australian continent in the Pleistocene
    - this sensitivity, combined with increasing modern and anthropogenic pressures further contracting their natural range may contribute to the extinction of localised populations (*better in climate change paragraph? mentioned there too, expanded on here?)

The importance of refugia

- Callaghan et al. 2015
  - abundance of arboreal mammals was influenced by topography ie higher abundance in gullies than slopes

Supports MacNally, Soderquist and Tzaros (2000) – specifically avian based survey but good supporting information for the importance of gully microclimates

- gullies are important mesic (or less xeric) refugia for species richness – one third greater in gullies than ridges
  - mean densities of birds almost twice as great
- assemblage composition of birds also varied significantly, indicating that mesic gullies and dried ridges work together to support a wider variety of species
- gullies or drainage lines – do not have to be permanently wet to provide microclimates as variable topography leads to differences in rainfall and humidity, including the accumulation of water from runoff etc, leading to differences in biodiversity
  - greater and more reliable food resources than on surrounding ridges
- these moister microclimates provide important refugia for wildlife from fire, and drought
- landscape heterogeneity is important for providing 'source' population areas

Black et al. (2014)

  - koalas that survived extreme drought and heatwave conditions were those that took refuge in the riparian habitat alongside permanent watercourses, and so trees maintained leaf/canopy cover during events

Chia et al. (2015)

- "Together, these findings highlight the importance of environmental variation and fire induced landscape heterogeneity in the aftermath of major wildfires. They are consistent with the view that mesic forest gullies and patches of unburnt or less-severely burnt forest (understory only burnt) have a role as refuges for arboreal mammals in severely burnt landscapes, and that such refuges assist the recovery of mammal populations after wildfire." – *not edited*

  - this fits in with McNally and Black on the conservation value of mesic gullies etc
  - Gullies are important refugia during fire and also valuable habitat long term after fire

Rehabilitation Potential

- (Lunney et al. 2004)
  - Above

Callaghan et al. (2011)

- This paper approaches koala conservation from a habitat and vegetation mapping perspective (koala suitability habitat mapping) and describes a methodology for building a Koala Habitat Atlas (KHA) for koala habitat quality, and including trees for both food (nutrition) and shelter (euc and non-euc), for local, regional and local scales
  - uses three classifications of tree/habitat quality
    - **Primary tree species** - euc species with a statistically significantly higher proportion of pellets and a high ranking for use vs availability
    - **Secondary** - euc species as above but not included in the above category, with med-high ranking for use vs availability
    - **Third** - supplementary euc species - lower fecal pellets present than secondary category, but more than other eucs around
  - habitat quality classes then assigned based on regional ecosystem types
- This paper has taken the approach that koalas will preferentially choose the tree species that are essential for survival and this can be determined by comparing the proportions of trees with koala pellets present underneath. This information can then be used to rank the use of euc species by koalas to categorise and map habitat quality.

The usefulness of citizen science

- wildlife rehabilitation also gives community members a change to get involved and become champions for the cause, raise awareness in local communities etc. Long-term community support is particularly important in supporting conservation programs (Lunney et al. 2004).

Markwell (2020)

- Examines the moral responsibility of the tourism industry with regards to ethics of care towards non-human stakeholders (animals) such as koalas, that it benefits from, considering it is a driver of climate change that is affecting those very animals

Limitations

- Limitations going forward
  - no detailed demographic studies – and Eden koala pop now below threshold size for such studies, which limits the ability to inform management

   - areas set aside in Tantawangalo and Yurammie SFs as NPs after the RFA processes were brought in in the late 1990s were too late for koala pops but remain as 'ghost habitat' for potential future popns (Lunney et al. 2014).

Callaghan et al. (2011)

- surveys using faecal pellets may be inaccurate as pellets can decay at different rates, and pellet detection rates can vary with the skill of the surveyor, ground cover, leaf litter etc HOWEVER this is less of a problem as active/non-active sites rely on pellet detection rather than pellet count
- The main issue with the KHA mapping approach is the limitations in the underlying vegetation mapping to delineate small patches of key koala habitat based on tree species

Recommendations/key management focus areas

Climate change

Anthropogenic threats

- clearing
- fragmentation
- isolation
- dogs
- vehicles

Lunney et al. (2014)

- localised threats that can be managed – logging, road traffic, dogs – must be managed
- At a local level, planning and strategies that reduce fragmentation can help manage local wildlife, allowing them to move across the landscape to find climate refuges
- localised threats that can be managed – logging, road traffic, dogs – must be managed
   - decrease in FPC due to logging led to decline in koala distribution
      - the view of the authors that high intensity logging removes habitat and are therefore a threat
      - Jurskis and Potter (1997) surmised that logging regrowth actually leads to koala increase – however authors judge this to be 'premature and ill-judged' as the koala pop in question in the Tantawangalo SF has since disappeared
- climate change a hitherto unrecognised major driver of declines and therefore should be an high agenda item for management at all levels including international.
- Felton et al (2009) – for effective conservation efforts to take place, the distinction between known and accepted land use impacts vs the impacts of climate change is challenging but necessary

McNally etc

- implications for management are that mesic gullies should be granted management priorities, and the cessation of activities that impact them heavily (alluvial gold mining, strip mining, clearing)

Chia et al. (2015)

- Implication for conservation
  - spatial heterogeneity is important for refugia, post-fire resources and post-fire repopulation
  - topography, fire intensity and time since last fire determined presence of unburnt patches – mostly in mesic gullies or recently burnt patches – indicating that protection of these areas (and including habitat areas of high value such as mature forest with old growth tree) and burning regimes to reduce fuel load, leading to less severe fires in these important areas could be a conservation focus
  - fire is not the only threat to manage – introduced predators, logging, human expansion/development, drought etc

Callaghan et al. (2011)

- Habitat mapping potential
- "The KHA provides a sound basis for koala-management planning to improve prospects for long-term conservation of koala populations."
  - the need for decisive conservation management in Noosa is underpinned by massive habitat loss, and results between the 1996/96 and 2001/02 surveys indicate population decline
  - it is equally important to provide protection and restoration to areas of known koala populations as it is to direct it towards areas of habitat suitability but low numbers. This can provide new habitat and corridors between well linked large patches.
  - importance of retaining large swathes of forests and landscape connectivity

- Black et al (2014)
  - management implications should be to prioritise creating and protecting habitat corridors between areas of future refugia, possibly translocations for genetic fitness

Lunney et al (2004)

- Important that rehabilitated animals (ie koalas) are returned to point of capture as translocation is often less successful

Matthews et al (2007)

- **Management conclusions**
  - not just focused on food trees
  - not be focused on individual trees, rather the qualities of the landscape patchiness that provides a mix of size classes and species for both food and shelter
  - koalas likely to be most vulnerable in burnt landscapes that are isolated from unburnt areas but likely to recolonise in areas that are less fragmented - therefore avoiding fragmentation should be highly considered in planning, especially as shelter tree species are not protected under the NSW planning instrument
  - study shows that greatest impact is through direct impact rather than temporary removal of resources
  - headlines stating that fires have wiped out koala habitat are misleading and detract from the real issues of deforestation, fragmentation and mortality through traffic incidents and dog attacks
- **Three key management points:**

- 1. complementary sampling techniques are likely to capture more data and therefore yield more information
- 2. day and night tracking/observation techniques advised as koala behaviour differs between the two
- 3. Scat searches under trees may indicate feed tree when in fact it is a rest tree, hence combining with radio tracking etc for a clearer picture

The references and full summary are at [https://eurokoalas.files.wordpress.com/2021/02/fire-literature-summary-and-references.docx].

Cristescu et al also published on the ***relationship between flora recovery and fauna recovery*** after fire [https://eurokoalas.files.wordpress.com/2021/02/cristescu-et-al_species-richness-and-tree-canopy-cover.pdf].

At the time of writing this report, new research was emerging constantly, prompted by the 2019-2020 fire season. An example is the DNA-oriented collaborative database involving Sydney University and partners. These kinds of initiatives will add substantially to the prior knowledge our project was able to access.

The use of a second datasheet and *NestForms* app to judge fire impact on koala habitat

Datasheet 2 was deliberately designed to help judge the immediate impact of fire on the habitat, and the post-fire quality and likelihood of persistence of that quality.

Datasheet 2 was used for every plot. Commentary on its effectiveness is at "FINDINGS – Fire" below.

Datasheet 2 for every plot can be viewed at the following links:

EMDSF Datasheets and Additional Information
https://eurokoalas.files.wordpress.com/2021/01/emdsf-datasheets-and-additional-information.zip

GDNP Datasheets and Additional Information
https://eurokoalas.files.wordpress.com/2021/01/gdnp-datasheets-and-additional-information.zip

GMSF Datasheets
https://eurokoalas.files.wordpress.com/2021/01/gmsf-datasheets.zip

Example – Completed Datasheet 2 for Plot EMDSF3

SECOND DATA SHEET FOR WAMBAN/NERRIGUNDAH SURVEYS 2020

F = flowering

FB = budding

Plot Number **EMDSF3**

Plot radius **25.8m**

Live Tree		Epicormic Shoots	Fire Damage as %age				**OTHER NOTES**	
per 1st		E = early						
datasheet	Species	A = advanced	Crown	Trunk	Roots		Soil samples taken:	
		P = post-epicorm				1	Surface	No
1	Eagg	**P = post-epicorm**	100	100	Nil	2	At Depth cm	
2 (F)(FB)	Angflo	**A**	100	100	Nil		***Ridge.***	
3	Econs	**A (basal)**	100	80	Nil		***Very high fire damage.***	
4	Esie	**A**	100	80	Nil		%age of trees on plot	
5	Esie	**A**	100	80	Nil		which appear killed by	
6	Econs	**P = post-epicorm**	100	100	Nil		fire (not incl. in the 30)	
7	Econs	**E**	100	100	Nil		**20%**	
8	Econs	**A**	100	100	Nil			
9	Econs	**A**	100	100	Nil		What killed them?	
10	Econs	**A**	100	100	Nil		Root burning	
11	Econs	**A**	100	100	Nil		Trunk burning	**X**
12	Econs	**A**	100	100	Nil		Chimney	
13	Eagg	**E**	100	100	Nil		Other	
14	Econs	**A**	100	80	Nil		Unclear	
15	Esie	**A**	100	70	Nil			
16	Esie	**A**	100	70	Nil		What understory	
17	Eglo	**A**	100	100	Nil		is returning? (incl. weeds)	
18	Econs	**A**	100	100	Nil		**11 x plants listed on**	
19	Econs	**A (basal)**	100	100	Nil		**separate sheet.**	
20	Esie	**A**	100	100	Nil		Status of any	
21	Esie	**A**	100	80	Nil		watercourses	
22	Esie	**A**	100	70	Nil		**Nil**	
23	Econs	**A**	100	100	Nil			
24	Econs	**A**	100	100	Nil		Evidence of	
25	Eagg	**A**	100	80	Nil		other animals	
26	Esie	**A**	100	80	Nil		not included on	
27	Econs	**P = post-epicorm**	80	70	Nil		Sheet 1	
28	Esie	**A**	100	80	Nil		**Nil birds.**	
29	Eagg	**A**	100	100	Nil			
30	Esie	**E**	100	100	Nil			

Later in the fieldwork the *NestForms* app became available as an additional record of fire impact on habitat.

The *NestForms* app was used for Plots EMDSF1, EMDSF2 and EMDSF3.

Detail on how the app worked is also at “FINDINGS – Fire” below.

ANALYSIS

Model of Analysis

Put simply the model of analysis was:

- Adapting RGBSAT
- Querying and cross-referencing amongst plot data and related references
- Analysing and overlaying Maps
- Interpreting, with mediation by reference to other research

The conceptual basis was as follows, working backwards from the end goal to our tools and data, and speculating on the capacity of QGIS to offer additional insights. (The multi factor statistical model "*MaxEnt*" suggested the latter might be effective: *Ecol Evol. 2017 Sep; 7(18): 7475–7489* - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5606888/)

Q	A
What is our end goal?	To estimate the quality of koala habitat across the Wamban-Nerrigundah patch. *(If the quality is judged to be good enough, there would be a subsequent goal of drawing out the implications for State and Local Government policy, planning and development approvals, and for the update & promotion of our Eurobodalla Koala Recovery Strategy.)*
What tools are we using?	• Excel spreadsheets and IT apps for individual plots • Background literature and previous research reports • Website, Facebook, Instagram & local knowledge • QGIS
What data do we have, or are we generating?	• Our own plot survey datasheets, old and new • Datasets and maps from SEED • Miscellaneous general data from Forestry Corporation, OEH and SCIVI sources eg descriptions of vegetation types, logging and fire history, and regional koala tree use patterns
What can QGIS do for us?	**Conclusions drawn post-analysis**
In the same way as multiple fields in a statistical database can be queried and cross-referenced to produce meaning, can	Yes. We consulted two specialists, who indicated this is a relatively easy process for people familiar with the software.

QGIS do this in a spatial and/or statistical way?	
Can we construct a model in QGIS (it can be done in ArcGIS) which will spit out a valid answer to our end-goal question (ie how good is the habitat?)?	Yes, up to the point where mediation through reference to the literature and local knowledge play their part in drawing conclusions. *n=10* is a constraint.
In QGIS (or elsewhere) can we use selected layers from SEED and our own plot surveys to produce a pattern amongst (at least some) of the previously researched habitat factors ie: • eucalypt species • size and crown class of trees • foliage cover scales • chemical composition of browse • geology and soil nutrients • altitude • steepness of slope • aspect • distance to viable water source • various disturbance types eg fire, flood, mining, farming, logging, roadworks, proximity to urban and peri-urban development • size of the patch in relation to known low density home range areas and connectivity corridors for breeding • weather history and microclimate?	Yes, but any factors selected from this list are dependent on the relevance and clarity of our starting data. A feasible example for us would be to generate plot-based numerical and map displays for values and relationships amongst factors like proximity of watercourses, soil type, slope, access and density of particular eucalypt species. At a future date, time permitting and with the help of a specialist, our GIS volunteer might conduct an exercise of this nature. This might be a helpful process for later projects and could produce unexpected insights, but because we are dealing with only ten plots with already transparent data and patterns, we consider it a low priority for our busy volunteer now. If any such exercise is conducted, we will attempt to upload it to the website for readers who have access to QGIS software. Alternatively, readers with GIS software can be put in direct touch with our GIS volunteer via https://eurokoalas.com/contact/ enabling them to explore our files.
Can QGIS (should we?) attribute meaningful weightings to the results for each factor?	Yes, but weightings imply a combination of assumptions based on previous research, and the presence of useful values in our data.
Pre and post fire: can we compare the old plots (W and N) with the new plots (G and EM) to look for meaningful differences that might result from the latest wildfire (eg plot radius, hence relative density of surviving trees)?	Yes, QGIS offers a way to go deeper into the results we obtained for this, but it's a superfluous luxury for our circumstances. Weaknesses in our data collection such as subjective estimates of the percentage of trees killed on plots and *n=10,* apply.

Suitability of Eucalypt Species - Cross-referencing SCIVI Vegetation Types with Koala Tree Use Survey

We cross-referenced the positive diagnostic eucalypt species for each SCIVI polygon in the project's polygon with the ratings for these species in the NSW Government Review of Koala Tree Use 2018 [op cit]. This produced the following information.

SCIVI classifications for total patch
Eucalypts amongst positive diagnostic species

Main subsets in this area

n183 South Coast Hinterland Wet Forest
Eucalyptus cypellocarpa, Eucalyptus fastigata, Eucalyptus longifolia, Eucalyptus muelleriana, Eucalyptus saligna X botryoides, Eucalyptus scias subsp. callimastha, Eucalyptus smithii

p89 Batemans Bay Foothills Dry Forest
Eucalyptus agglomerata, Eucalyptus consideniana, Eucalyptus globoidea, Eucalyptus paniculata subsp. paniculata, Eucalyptus sieberi

p100 Escarpment Foothills Wet Forest
Eucalyptus muelleriana, Eucalyptus piperita, Eucalyptus smithii

Smaller subsets

p40 Temperate Dry Rainforest
Eucalyptus botryoides

e32A Deua-Brogo Foothills Dry Shrub Forest
Eucalyptus agglomerata, Eucalyptus bosistoana, Eucalyptus consideniana, Eucalyptus globoidea, Eucalyptus longifolia, Eucalyptus muelleriana, Eucalyptus sieberi, Eucalyptus tricarpa

e4 Brogo Shrub Forest
Eucalyptus smithii

e19 Bega Wet Shrub Forest
Eucalyptus angophoroides, Eucalyptus baueriana, Eucalyptus bosistoana, Eucalyptus botryoides, Eucalyptus elata, Eucalyptus globoidea, Eucalyptus maidenii, Eucalyptus viminalis

e31 Southeast Hinterland Dry Grass Forest
Eucalyptus angophoroides, Eucalyptus bosistoana, Eucalyptus cypellocarpa, Eucalyptus elata, Eucalyptus globoidea, Eucalyptus maidenii, Eucalyptus muelleriana, Eucalyptus sieberi

e34 Southeast Coastal Gully Shrub Forest
Eucalyptus baueriana, Eucalyptus bosistoana, Eucalyptus cypellocarpa, Eucalyptus elata, Eucalyptus globoidea, Eucalyptus longifolia, Eucalyptus muelleriana

e46B Southeast Lowland Dry Shrub Forest
Eucalyptus globoidea, Eucalyptus pilularis, Eucalyptus sieberi

p90 Batemans Bay Cycad Forest
Eucalyptus fibrosa, Eucalyptus globoidea, Eucalyptus longifolia, Eucalyptus muelleriana, Eucalyptus paniculata subsp. paniculata, Eucalyptus pilularis

p91 Clyde-Deua Open Forest
Eucalyptus agglomerata, Eucalyptus bosistoana, Eucalyptus cypellocarpa, Eucalyptus muelleriana, Eucalyptus sieberi, Eucalyptus smithii

p98 Clyde-Deua Ridgetop Forest
Eucalyptus globoidea, Eucalyptus muelleriana, Eucalyptus radiata subsp. radiata, Eucalyptus sieberi

KMAs with documented levels of use for feeding, shelter or social purposes

Species	High use KMA	Significant use KMA	Irregular use KMA	Low use KMA
E saligna		North Coast	Central Coast	
E scias		Central Coast		
E botryoides		Central Coast		
E longifolia	Central Coast; South Coast			
E cypellocarpa	Central Coast; South Coast		Southern Tablelands	
E bosistoana	Central Coast; South Coast			
E paniculata	Central Coast			
E tricarpa	South Coast			
E muelleriana	South Coast			Central Coast
E globoidea	Central Coast; South Coast	North Coast		Central & Southern Tablelands
E agglomerata	Central Coast		South Coast; Central & Southern Tablelands	

E fastigata				South Coast
E sieberi	Central Coast	South Coast	Central & Southern Tablelands	
E consideniana		South Coast		Central Coast
E piperita		Central Coast; Central & Southern Tablelands	North Coast	
E smithii				Central Coast
E angophoroides	*No data as yet*	*No data as yet*	*No data as yet*	*No data as yet*
E baueriana			Central Coast; South Coast	
E maidenii	South Coast			
E elata		Central Coast		South Coast
E pilularis	Central Coast	North Coast		
E radiata	Northern Tablelands	Central Coast	Central & Southern Tablelands	
Some potentially relevant additions				
C maculata			North Coast; Central Coast; South Coast	
A floribunda		South Coast; Northern Tablelands	North Coast; Central Coast	North West Slopes
A costata		North Coast		Central Coast
A littoralis			North Coast	Central Coast; South Coast; Northern Tablelands; Central & Southern Tablelands
Acmena smithii (Lilli Pilli)				South Coast

<u>Suitability of Eucalypt Species - Cross-referencing ALL TREES FOUND ON PLOTS with Koala Tree Use Survey</u>

In this case we cross-referenced trees found on the 10 plots with the Government Review as follows.

Species	Number found per plot, and total number found	High use KMA	Significant use KMA	Irregular use KMA	Low use KMA
E sieberi	GDNP1 x 11 GDNP2 x 0 GDNP3 x 0 GDNP4 x 3 GDNP5 x 2 GMSF1 x 0 GMSF2 x 0 EMDSF1 x 17 EMDSF2 x 13 EMDSF3 x 10 **TOTAL x 56**	Central Coast	South Coast	Central & Southern Tablelands	
E globoidea	GDNP1 x 14 GDNP2 x 4 GDNP3 x 12 GDNP4 x 5 GDNP5 x 13 GMSF1 x 11 GMSF2 x 13 EMDSF1 x 8 EMDSF2 x 16 EMDSF3 x 1 **TOTAL x 97**	Central Coast; South Coast	North Coast		Central & Southern Tablelands
Angophora costata	GDNP1 x 2 GDNP2 x 1 GDNP3 x 10 GDNP4 x 5 GDNP5 x 6 GMSF1 x 10 GMSF2 x 0 EMDSF1 x 0 EMDSF2 x 0		North Coast		Central Coast

	EMDSF3 x 0 **TOTAL x 34**				
Corymbia gummifera	GDNP1 x 2 GDNP2 x 0 GDNP3 x 6 GDNP4 x 15 GDNP5 x 0 GMSF1 x 0 GMSF2 x 0 EMDSF1 x 0 EMDSF2 x 0 EMDSF3 x 0 **TOTAL x 23**		Central Coast	North Coast; South Coast	
E muelleriana	GDNP1 x 0 GDNP2 x 8 GDNP3 x 0 GDNP4 x 2 GDNP5 x 0 GMSF1 x 3 GMSF2 x 0 EMDSF1 x 0 EMDSF2 x 0 EMDSF3 x 0 **TOTAL x 13**	South Coast			Central Coast
Angophora floribunda	GDNP1 x 0 GDNP2 x 10 GDNP3 x 0 GDNP4 x 0 GDNP5 x 0 GMSF1 x 0 GMSF2 x 0 EMDSF1 x 3 EMDSF2 x 0 EMDSF3 x 1 **TOTAL x 14**		South Coast; Northern Tablelands	North Coast; Central Coast	North West Slopes
E paniculata	GDNP1 x 0 GDNP2 x 7 GDNP3 x 0 GDNP4 x 0 GDNP5 x 8 GMSF1 x 3 GMSF2 x 16 EMDSF1 x 0 EMDSF2 x 0 EMDSF3 x 0 **TOTAL x 34**	Central Coast			

E elata	GDNP1 x 0 GDNP2 x 0 GDNP3 x 1 GDNP4 x 0 GDNP5 x 0 GMSF1 x 0 GMSF2 x 0 EMDSF1 x 0 EMDSF2 x 0 EMDSF3 x 0 **TOTAL x 1**		Central Coast		South Coast
E obliqua	GDNP1 x 0 GDNP2 x 0 GDNP3 x 1 GDNP4 x 0 GDNP5 x 0 GMSF1 x 0 GMSF2 x 2 EMDSF1 x 0 EMDSF2 x 0 EMDSF3 x 0 **TOTAL x 3**		South Coast	Northern Tablelands; Central & Southern Tablelands	
E agglomerata	GDNP1 x 0 GDNP2 x 0 GDNP3 x 0 GDNP4 x 0 GDNP5 x 1 GMSF1 x 3 GMSF2 x 0 EMDSF1 x 0 EMDSF2 x 0 EMDSF3 x 4 **TOTAL x 8**	Central Coast		South Coast; Central & Southern Tablelands	
E bosistoana	GDNP1 x 0 GDNP2 x 0 GDNP3 x 0 GDNP4 x 0 GDNP5 x 0 GMSF1 x 0 GMSF2 x 1 EMDSF1 x 0 EMDSF2 x 0 EMDSF3 x 0 **TOTAL x 1**	Central Coast; South Coast			
E cypellocarpa	GDNP1 x 0 GDNP2 x 0 GDNP3 x 0	Central Coast; South Coast		Southern Tablelands	

	GDNP4 x 0 GDNP5 x 0 GMSF1 x 0 GMSF2 x 0 EMDSF1 x 2 EMDSF2 x 1 EMDSF3 x 0 **TOTAL x 3**				
E considениana	GDNP1 x 0 GDNP2 x 0 GDNP3 x 0 GDNP4 x 0 GDNP5 x 0 GMSF1 x 0 GMSF2 x 0 EMDSF1 x 0 EMDSF2 x 0 EMDSF3 x 14 **TOTAL x 14**		South Coast		Central Coast

Concentrations of species occur at different places in the polygon. E consideniana was only found in Plot EMDSF3.

The four species with the largest numbers across all plots were E globoidea (97; common across most plots), E sieberi (56; mostly in GDNP1, EMDSF1-3), A costata (34; mostly in GDNP3 and GMSF1) and E paniculata (34; four plots only, mostly GMSF2).

This variability amongst plots supports the view that koalas living in such a landscape would need to move from place to place to obtain the range of browse required for their diet.

On the other hand, the tables above support the view that the most commonly occurring eucalypts are valuable koala feed species, and taken together offer an adequate diet.

From a technical research perspective, the similar patterns of variability amongst both the SCIVI classifications and this study's ground-truthing approach, reinforce the validity of both.

Caveats:

- SCIVI was as much modelling and the aggregation of remote data, as it was ground-truthing through site visits
- This Gilmore study only conducted 10 plots across a much larger patch

- There are gaps in the NSW Review because places like the Eurobodalla and Southern Shoalhaven (where species like E paniculata occur commonly) have such low numbers of koalas that pellet counts haven't been done there, so the only available E paniculata rating (albeit "High Use") is for the Central Coast
- In the absence of pellet counts for extreme low-density koala landscapes, evidence for the impact of non-browse factors such as soil and topography, is less clear

Slope

As mentioned previously, estimated slopes recorded on the plot datasheets were:
1 plot @ 5-10 degrees
2 plots @ 15 degrees
1 plot @ 20 degrees
4 plots @ 30 degrees
2 plots @ 35 degrees
While this pattern suggests four of the ten plots are optimal for koalas [Hammond, op cit], the other six are not, and their sites were influenced by the need to find places gently sloping enough for volunteers to access and work on.
Combined with the complex crumpled folding across the whole landscape, this feature probably points more to an inhibitor to koala movement than it does to an opportunity.

Aspect

A similar picture emerges for aspect. Datasheets recorded the following:
3 plots @ aspect North
2 plots @ aspect North-West
1 plot @ aspect North-East
1 plot @ aspect West
1 plot @ aspect North-North East
1 plot @ aspect East North-East
1 plot @ aspect South-East
Although it's arguable that 7 or 8 of the ten plots are close to optimum, it has to be assumed the crumpled nature of the landscape will produce many locations facing in all directions.

Shade and Tree Canopy Cover

The caveat here is that these plot surveys were conducted well within the first year after hot wildfire.
For two plots, the shade was recorded as "Open". For the rest it was recorded as "Dappled" (a common descriptor even in unburnt plots).
Tree canopy cover was recorded as "Thin" for three plots and "Medium" (also common in unburnt plots) for the rest.
These observations don't seem to produce any significant outcome for the analysis, except to show there is no heavy shade for shelter on any plot.

Access to Water

No water (except a couple of post-rain puddles) was recorded at the plot sites per se, although a water crossing was required for foot-access to one GDNP plot (Wamban Creek), and a short side-excursion by vehicle from a GMSF plot to view a healthy flow after recent rain (Bumbo tributary) was undertaken.

Geology and Soil

The underlying geology of the patch described previously, is not ideal for koala habitat according to previous research, except for the alluvial parts at the Wamban and Nerrigundah nodes.

One plot survey external to this funded study, on private property at Wamban (Plot SPS1) was at geological code *Oada*, on deep loam. The 22.4m radius plot was dominated by E angophoroides, with a mix of E globoidea, Angophora floribunda, Allocasuarina littoralis and a single E tereticornis. Near the plot were concentrated stands of E tereticornis and E globoidea. This single property's characteristics are evidence for the notion that the Wamban node is a potentially useful home range area.

The geology (*Dmew* and *Dmeb*) and soil in the postulated breeding corridor between Wamban and Nerrigundah however, are poorer.

Soil samples from Plots GDNP2, GDNP4, GMSF1 and EMDSF1 were analysed by APAL (Australian Precision Ag Laboratory). The full analysis is at [https://eurokoalas.files.wordpress.com/2021/02/apal-soil-analysis-zip.zip].

For the crop type "Forestry", readings for Nitrogen and Potassium (two presumed nutrient-relevant components) for example, are as follows:

Plot Number & Soil Texture found	Component	Unit	Desired Level	Level Found
GDNP2 – Silty Loam	Extractable Nitrate	mg/kg	20-50	35
GDNP2 – Silty Loam	Exchangeable Potassium	%	3.00-8.00	5.70
GDNP4 – Sandy Loam	Extractable Nitrate	mg/kg	20-50	<1
GDNP4 – Sandy Loam	Exchangeable Potassium	%	3.00-8.00	8.40
GMSF1 – Silty Loam	Extractable Nitrate	mg/kg	20-50	<1

GMSF1 – Silty Loam	Exchangeable Potassium	%	3.00-8.00	6.30
EMDSF1 – Sandy Loam	Extractable Nitrate	mg/kg	20-50	<1
EMDSF1 – Sandy Loam	Exchangeable Potassium	%	3.00-8.00	6.90

Organic carbon content for each plot (presumably influenced by hot wildfire) was listed as follows:

GDNP2 - Excessive

GDNP4 – Acceptable (high end of the range)

GMSF1 - Excessive

EMDSF1 - High

The available pre-fire comparisons were from the 2013 Bendethera study (Deua National Park – Deua River) Plots BE3 (Loam on river flat) and BE14 (Sandy Loam on river flat) as follows:

Plot Number & Soil Type	Component	Unit	Level Found
BE3 - Loam	Exchangeable Nitrate	mg/kg	39.74
BE3 - Loam	Exchangeable Potassium	%	9.02
BE14 – Sandy Loam	Exchangeable Nitrate	mg/kg	17.56
BE15 – Sandy Loam	Exchangeable Potassium	%	4.66

The full Bendethera soil analysis report is at [https://eurokoalas.files.wordpress.com/2021/02/full-bendethera-soil-analysis.docx].

The great majority of soil in the potential breeding corridor between Wamban and Nerrigundah appears poor in Nitrate, and questionable overall when the full analysis is consulted.

Although Potassium looks acceptable as a percentage, when measured as mg/kg two of the plots are listed as having "Low" exchangeable Potassium cations.

Iron is rated "High" in three plots and "Acceptable" in Plot GDNP4. Aluminium and Manganese are overall "High".

As mentioned previously, Kurosols subsoil is strongly acid, ie pH is 5.4 or less in water, and non-sodic. Rudosols are also strongly acid.

The APAL analysis found pH to be:

- 5.62 (Low - cf desired range for Forestry 6.5-7.5) in the Plot GDNP2 sample
- 5.77 (Low) in GDNP4
- 5.00 (Very Low) in GMSF1
- 5.15 (Very Low) in EMDSF1

The desired level for Sodium is 5% to 6%. The APAL analysis found the GDNP2 sample Sodium level was 3.8%, GDNP4 was 3.1%, GMSF1 was 4.6% and EMDSF1 was 3.6%.

Fire Impact

The following link is a Facebook video of October 2020 images showing volunteers at burnt and unburnt private and public lands, within and outside the studied polygon. It gives some impression of conditions ten months after the fires [https://eurokoalas.files.wordpress.com/2021/02/october-2020-images-facebook-video-zip.zip].

Leaving aside the impact on soil, data collected for fire impact concentrated on vegetation.

Across the whole range of plots (except Plot GDNP3, recorded as having none), returning undergrowth was listed by volunteers as follows [plot-by-plot variation can be seen in *Datasheet 2* and *Additional Information Sheets*, op cit].

Shrubby species Brush Kurrajong Macrozamia communis Sedges Solanum prinophyllum Xanthorrhoea sp Philotheca sp Lomatia ilicifolia (‘Native Holly’) Hardenbergia sp Pimelea sp Lomandra sp (several)	Eucalypt recruit Macrozamia communis (Burrawangs) Kennedia rubicunda Acacia sp - mearnsii, salicina, ulicifolia Stylidium sp Lobelia dentata Dianella sp (cerulea) Lomandra sp Antalasia restricta? ‘Blueberry Ash’?	Allocasuarina littoralis Philotheca sp Bursonia sp Dianella sp (longifolia?) Trerulea Allocasuarina littoralis Kennedia rubicunda Phylothera sp Bracken fern Acacia sp Lomandra confertifolia Lepidosperma neesii Melaluca sp

Datasheet 2 also demonstrates the stage epicormic shoots have reached for every tree, mostly “Advanced” at the time of surveying, except for Plot GDNP3 where they are recorded as equally “Early” and “Advanced”.

Datasheets 1 and 2, the Additional Information Sheets and plot photos also show surviving or returning fauna. Across the whole range of plots, volunteers listed the following fauna present at the time (*Note: distribution differed amongst the plots*). The photos show more, especially some small invertebrates.

Wallaby Wombat Wedge-tailed eagle Bird species Grey fantail (Rhipidura albiscapa) Spotted pardalote (Pardalotus punctatus) Golden whistler (Pachycephala pectoralis)	Eastern whipbird (P nig) Grey shrike-thrush (C harm) Fantailed cuckoo (Cacomantis variolosus) Willie wagtail White-throated treecreeper (Cormobates leucophaea) Yellow-faced honeyeater (Caligavis chrysops) Bell miner (M mel)	Cicadas Jacky (Mountain) dragon Emperor gum moth Grey butcherbird Grasshoppers Native bees Rufous whistler Eastern yellow robin

For comparison, on 2nd July 2020 (six months post-fire) the private property owner at Buckenbowra/Runnyford previously mentioned had indicated the following pattern of animals returning after the fire.

"Bowerbirds returned early.
Warblers, Lorikeets (large & small), King Parrots, Glossy Red Cockatoos, Wattlebirds (lots of them) & Friar Birds have all returned.
As a general rule the smaller birds are proving slower to return.
There are Boobook Owls calling.
One possum.
Wombats, Wallabies and Grey Kangaroos are back."

<u>Querying Datasheet 2</u>

There are numerous ways the figures generated by Datasheet 2 can be displayed to try and gain a perspective on how badly the browse species were impacted by fire, and the likelihood of recovery. Below is a table created for all trees. This could be further broken down into the relative damage to different tree species and tree sizes.

NB: The figures below for trunk damage (@ 100%) are crude, because there were many not included in this summary table with damage ranging up to 90% (*see full datasheets for accuracy*).

Plot numbers (300 live trees)	Number of live trees with 100% canopy damage	Number of live trees with 100% trunk damage	Estimated percentage (%) of trees killed on the plot	Plot radius (metres)
GDNP1	30	27	20	23.4
GDNP2	30	0	10	20.7
GDNP3	30	30	10	25.8
GDNP4	3	11	Not recorded	25
GDNP5	1	1	Not recorded	36
GMSF1	30	0	10	14.8
GMSF2	30	27	20	25

EMDSF1	27	30	15	30.7
EMDSF2	30	0	4	27.1
EMDSF3	29	18	20	26
Totals	**240**	**144**		
Average/Mean	**24**	**14.4**	**13.625**	**25.45**
Median			**12.5**	**25.4**
Mode				**25**
Range			**16**	**21.2**

Because the measured trees were deemed to be alive and had epicormic shoots, often at the advanced stage, it might be assumed they will survive long-term. There were two good rain events after the fires as the *la nina* weather pattern commenced.

The estimated percentage of trees killed on each plot (subjective visual judgement by field volunteers) and the measured radius of each plot might be helpful for predictions.

Rates of fire-killed trees were 4% to 20%, with Mean 13.625, Median 12.5 and Range 16. That produces a 17.78% difference in the number of browse trees between the pre-fire plots and the post-fire plots.

The ten plot radii can be compared with those for the pre-fire plots surveyed in 2012-13, ie Plots W1-9 and N1, to extrapolate an idea of the relative density of trees on plots before and after the 2019-20 fires.

Plot Group	Mean	Median	Range
GDNP1-5, GMSF1-2 & EMDSF1-3	25.45	25.4	21.2
W1-9 & N1	20.749	18.45	14.8

Using the Median, this table produces a 15.85% difference in the plot radii between the pre-fire plots and the post-fire plots.

Although *n=10* is ridiculously small and cannot be considered representative of a whole landscape, these figures are provocative and prompt speculation that potential koala habitat has been reduced by over 15% thanks to the 2019-2020 wildfires.

The rate of long-term recovery (after the initial benefit from epicormics) would seem to depend on the time it takes eucalypts to grow to DBH 150mm on low-nutrient soils, hence the danger of permanent loss if hot wildfires occur every couple of decades or less. [*Note:* The *Koala Clancy Facebook page* (February 2021) remarked that most people assume a 10 to 20 year period for trees to grow to a size suitable for koalas to eat, but in fact 4 to 6 years can be enough.]

Further cross-referencing with items in Datasheet 1 such as DBH figures, might permit more nuanced perspectives. For example, trees in Plot GDNP1 have DBH from 150mm to 702mm. The Mean is 315.6, the Median is 265 and the Range is 552. Rates of burning and epicormic shooting however, appeared unrelated to tree species or DBH when Datasheet 2 for all plots was overviewed.

Data from the *NestForms* app for Plots EMDSF1-3 are available, including photographs and audio at [https://eurokoalas.files.wordpress.com/2021/02/data_from_nestforms_app.zip] in a zip file with data for some private property plots. The table below replicates the text inputs for the EMDSF plots.

Name; date; time	**Plot EMDSF1_15/10/20 11:13 am**	**Plot EMDSF2_15/10/20 12:53 pm**	**EMDSF3_15/10/20 2:00 pm**
Species	Cicada	Cicada	Cicada
Landscape position	Ridge or hill	Ridge or hill	Ridge or hill
Vegetation type	Eucalypt forest (grassy)	Eucalypt forest (grassy)	Eucalypt forest (grassy)
Growth stage	Mature (many mid-life trees)	Mature (many mid-life trees)	Mature (many mid-life trees)
Fire severity	Extreme (trees burnt - leaves and fine twigs mostly consumed)	Extreme (trees burnt - leaves and fine twigs mostly consumed)	Extreme (trees burnt - leaves and fine twigs mostly consumed)
Ground layer recovery	New growth visible	New growth visible	New growth visible
Shrub layer recovery	Seedlings present	Both shoots and seedlings present	Seedlings present
Sub canopy recovery	No sub canopy present	Shoots present	No sub canopy present
Tallest canopy recovery	Epicormic and basal shoots present	Epicormic and basal shoots present	Epicormic and basal shoots present
Presence of flowering plants	Ground layer - plants are currently flowering. Upper canopy layer - plants are currently flowering	Ground layer - plants are currently flowering	Ground layer - plants are currently flowering. Upper canopy layer - plants are currently flowering

FINDINGS

Research Method

Adapting RGBSAT (the Regularised Grid Based Spot Assessment Technique) to the purpose of estimating the quality of potential koala habitat for the Wamban-Nerrigundah patch has permitted close-scale ground-truthing at ten locations.

The analysis demonstrates that eucalypt species, slope, aspect, shade, tree canopy cover, soil data and some indications for water access could all be collected in the field, and some of these factors could be validated against the SEED Repository maps, the NSW Review of Koala Feed Tree Use and the collection of materials addressed in BACKGROUND AND PREVIOUS RESEARCH above.

The data collection extensions for Fire, ie Datasheet 2 and the *NestForms* app enhanced the analysis of fire impact and provided some insights into potential habitat recovery rates. Their analysis benefited from the mediation role of desktop research.

QGIS provided high resolution map displays at various scales, cross-referencing and the potential for multi-layering and multi-factor querying in analysis and for reporting.

The *Avenza*, *Australian Topo Maps* apps and others on volunteers' devices like *GPS Test* and *GPS Tools* permitted accurate route planning, tracking, readings of altitude, GPS coordinates and assisted with flora identification and slope estimates in the field.

Quality of the habitat patch

- Eucalypt species across the patch are suitable for koala browse and a comprehensive diet, provided caveats about the soil nutrition level and the need for koalas to move between intra-patch locations for full species diversity, are taken into account.
- Shade and tree canopy cover conditions are still suffering from hot wildfire impact, but should recover to provide medium quality.
- Topography between the narrow flatlands beside Wamban Creek and Gulph Creek is rugged. On the one hand numerous places within the polygon attract optimum ratings for the habitat factors slope and aspect. On the other hand, these locations are part of complex ridge systems with steep slopes.
- Soil across the patch is generally low in nutrition, and this appears unrelated to fire impact.
- Access to reliable water is reasonably good during non-drought conditions.
- The contextual climate and altitude conditions suit koalas.
- Recovery that should maintain the habitat after the 2019-20 fires is already occurring, indeed the current level of epicormic shooting is potentially a temporary

enhancer. On the other hand, it might take many years for the full density of sizeable eucalypts to regrow because a minority appears to have been killed by fire.

CONCLUSIONS and RECOMMENDATIONS

Conclusions

Glass half-full perspective: The study confirms the viability of the Wamban-Nerrigundah patch as koala habitat for an albeit low-density population, taking into account local koala history and the soil nutrition and topography caveats. The habitat will not suffer serious long-term effects from the 2019-2020 fires, provided severe wildfires do not begin recurring within twenty-year periods. Accordingly, the patch might represent part of a future "safety valve" location for NSW koalas in low density circumstances. The necessary browse species are certainly in place.

Glass half-empty perspective: Twenty-first Century koala numbers in the Eurobodalla were already so low before the 2019-2020 wildfires that confirmed sightings were only occurring about twice per decade, however stories persisted of koalas on private property around Eurobodalla Road for example. So far, no reports have surfaced at Wamban or Nerrigundah since the fires. If an extremely low-density population still exists, the intensity of future disturbance will decide its long-term survival. The cumulative impact of severe fires since 1952, combined with historical clearing on alluvials, rugged topography and low-nutrition soils on ridges, might mean the local population is already at risk of extinction. Severe wildfire is predicted to become more frequent. It could combine with further vegetation fragmentation or deterioration through dieback, urban expansion or over-exploitive agri-industry. In these circumstances, any positive conclusions in this study no longer apply.

Advantages and disadvantages of the patch as habitat

Advantages include the diversity, size and age of suitable eucalypt species, the temperate climate, numerous spaces with north and west facing aspect, numerous spaces (albeit isolated) with optimum-to-good slopes (20 to 30 degrees for example), access to reliable water such as Wamban Creek and Gulph Creek, flora resilience after wildfire, and the regional landscape scale of vegetation connectivity afforded by the presence of State Forests and National Parks.

The outstanding disadvantage is the overall topography and soil composition of the studied patch, where the gentler slopes and loamier narrow river flats around Wamban and Nerrigundah are connected only through a complexity of rugged sandy-loam ridges, making the breeding corridor challenging though not in the researchers' view prohibitive. These topographic and soil features probably ensure only a low-density koala population would ever persist in the best-case future scenario, perhaps with a few scattered higher density groups at prime locations, as in the mid-Twentieth Century (history appears to suggest a widespread low-density population with higher densities in pockets).

Time, Natural Revival and Reintroduction

If a small remnant koala population has survived the latest wildfires (or if koalas can migrate to Nerrigundah-Wamban from places like Murrah where confirmed sightings are still occurring) a period of time is required for its recovery.

Indigenous cultural burning practitioners suggest a two-to-three-year period between cool burns [Morgan, pers comm & White pers comm; *Fire and Koalas* South East Zoom Conference, 2020]. The cultural burns do not normally impact on trees at canopy level, however.

Chia et al, 2015 (in Jasmin Bourne's summary, above) found fire was affecting arboreal mammal abundance 2.5 years on, and 3.5 years on in severely burnt areas.

In their comprehensive study of the impact of climate change and other factors on koalas in the Eden Region, Lunney et al 2013 [https://eurokoalas.files.wordpress.com/2021/02/lunneystalenberg2013-extinctionineden.pdf] concluded the rate of decline in that koala population was 70% every ten years.

Testing the Jurskis theory

As an added outcome, this Gilmore Electorate study has prepared the ground for testing (in Deua National Park, Moruya State Forest and Dampier State Forest) the argument that koala populations "irrupt" after a few years in post-wildfire forests that are left without regular cool burns [Jurskis, op cit]. By the time of the drone images we could already see the fresh shoots on trees (though no thick understory yet).

The Jurskis argument is well contested by Lunney et al [op cit] but receives some reinforcement from the early history of European settlement in Sydney described by Karskens, suggesting pre-existing low density [Karskens, Grace, "People of the River", Allen & Unwin, 2020].

So, it seems there would be little difficulty in testing the Jurskis prediction by pure observation as part of a more significant purpose over the next three to ten years.

Weaknesses in the analysis, and conclusions where evidence is least strong

- Browse value of eucalypt species where no data exist for the South Coast
- Soil sample comparisons between the Gilmore Project plots (all Sandy Loam on ridges) and Bendethera (both loamy on river flat)
- Importance of the 1952, 1968 and 2019-20 fires over others
- Percentage of trees killed and its impact on habitat

- Recovery rate and increased fire frequency

Best Option

Protection of habitat to permit natural revival seems the most sensible option for those wanting koalas to persist in the Wamban-Nerrigundah patch. The known difficulties associated with translocation combined with the sub-optimal aspects of this habitat patch, render the translocation option unwise except as a last resort.

Recommendations

1. Land managers and relevant agencies should actively monitor for three to ten years before judging whether a low-density koala population has survived or naturally revived in this area.
2. A community-based survey technique should be implemented [Lunney et al 2013, op cit].
3. If evidence of such koala presence emerges, a Comprehensive Koala Plan of Management (KPoM) should be designed to suit the location, and implemented.
4. If no evidence of koala presence emerges, the option of reintroduction through translocation can then be explored in light of contemporary knowledge.
5. The revised Eurobodalla Koala Recovery Strategy (2021) should be implemented immediately, even while monitoring is going on.

DISCUSSION

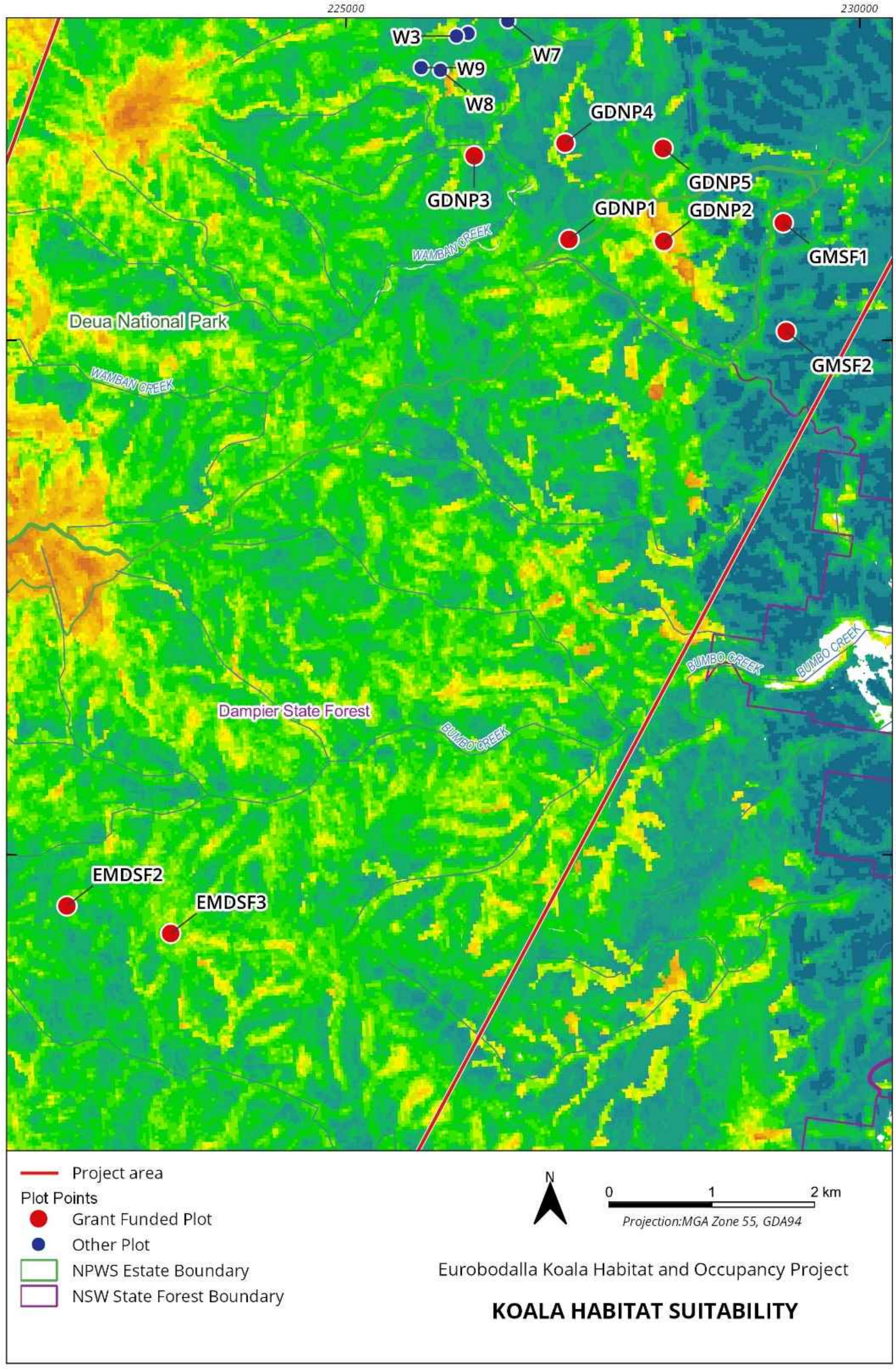
The ongoing Coastwatchers-sponsored volunteer Eurobodalla Koala Project is pursuing the notion that this LGA's temperate climate and remnant forests could become a vital safety valve for low-density koala revival or reintroduction in light of the dramatic modern population declines elsewhere in NSW caused by urban development, landscape drying through climate change and increasingly intense bushfire.

For example, the project's Pilot Study [op cit] suggested a swathe of worthwhile habitat exists including Bodalla State Forest (adjacent to the Gilmore Electorate/Eden-Monaro Electorate patch) where a koala sighting in a burnt-out area was reported by a NSW Forestry Corporation employee on 3rd February 2020 [Perkins/Dunne pers comms]. Recent material such as the **Koala Habitat Suitability** and **Koala Tree Index** datasets in SEED [op cit] reinforce these impressions.

The Koala Habitat Suitability Model

Provides a measure of koala habitat suitability at any location. The model predicts the likelihood of finding habitat that is ecologically similar to where koalas have been observed over the past 40 years.

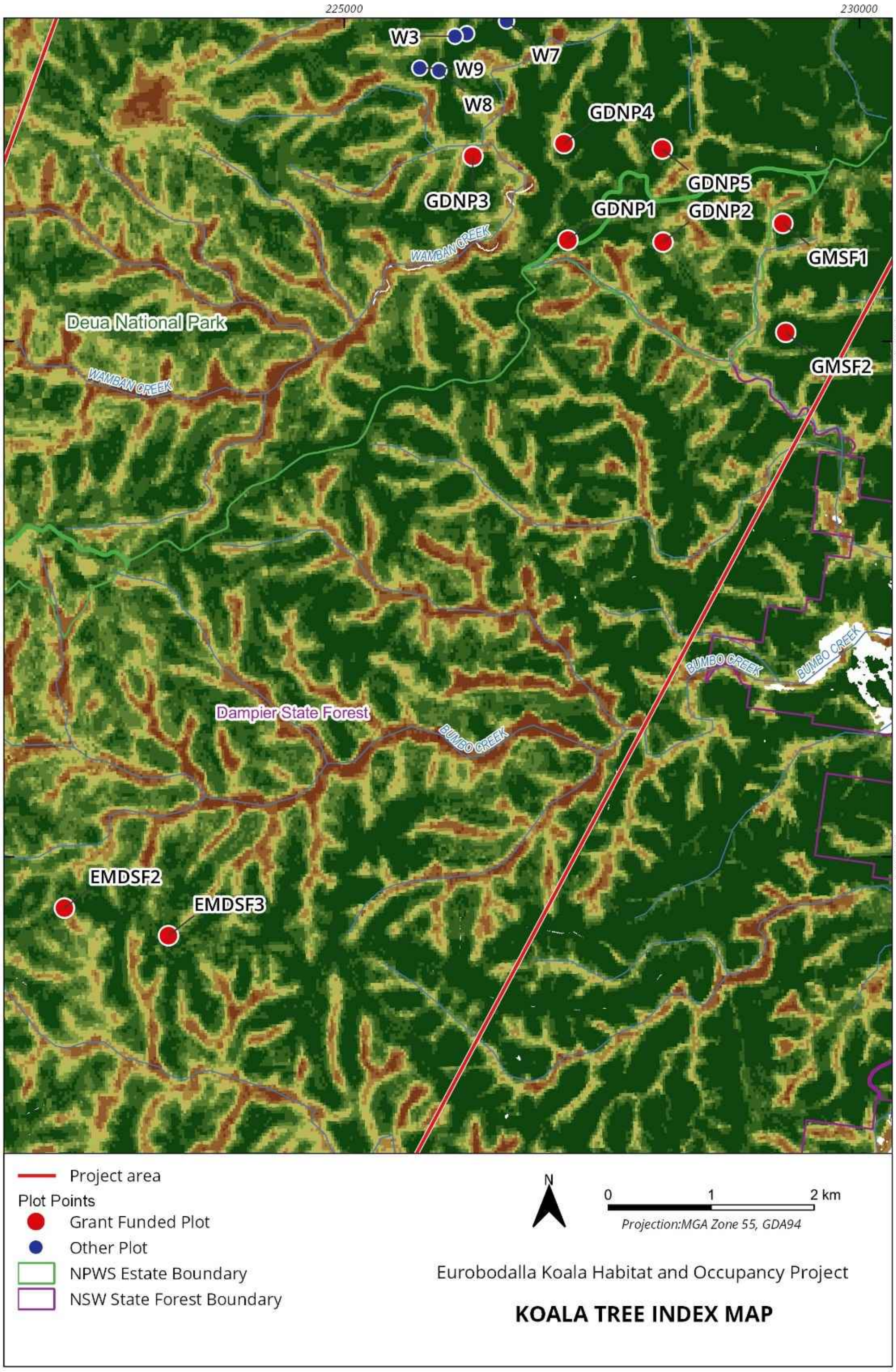
Refer to the BioNet web page to interpret the colours accurately. In this first map blue is highest and yellow is lowest.



The Koala Tree Index

Provides a measure of the probability of finding a tree species that koalas are known to prefer for food or shelter.

Refer to the BioNet web page to interpret the colours accurately. In this second map brown is highest and green is lowest.



Potential breeding connectivity across and beyond the Eurobodalla to known koala populations at Bermagui, Badja, Nerriga and Bungonia for example, is one of the project's foci, as is the investigation and rectification of historical vegetation fragmentation.

A series of plot surveys on private properties has begun, demonstrating most peri-urban and some urban locations across and near the Eurobodalla possess diverse koala browse species within and between themselves, and identifying spaces where fragmentation needs redress to ensure viable connectivity for wildlife.

These landholders express strong enthusiasm for protection of their habitat and there is significant interest in the idea of reviving local koalas through translocation from elsewhere (see Recommendation 3 above.)

The Coastwatchers Association Inc and the Eurobodalla Koala Project intend using this Gilmore Project's knowledge as a springboard for promoting the revised Eurobodalla Koala Recovery Strategy.

The Recovery Strategy Revised Edition may be used as a ready reference for agencies, land managers, not-for-profits, businesses and communities to preserve and rehabilitate habitat, and encourage koala revival.

The 2013 edition (now obsolete and only partially implemented) is available in the interim at [http://www.coastwatchers.org.au/final-eurobodalla-koala-recovery-strategy/] and contains still useful recommendations to Eurobodalla Shire Council, Forestry Corporation NSW, National Parks and Wildlife Service and private landholders about deliberate steps for preserving and enhancing habitat quality and connectivity across the wider Eurobodalla landscape and beyond.

The volunteer Eurobodalla Koala Project (EKP) will also use this Gilmore study's model of analysis as a basis for a 2021 carrying capacity study of the East Lynne area, and a review of the koala habitat significance of Bodalla State Forest.

The EKP will be further encouraging all public and private land managers as well as private entrepreneurs to exploit the Eurobodalla's koala history, and to maintain and rehabilitate habitat for business, cultural and biodiversity reasons.

The EKP's public awareness campaign has benefited greatly both from the program of plot surveys on private properties, and from widespread interest in the Gilmore Electorate study itself.

Part of this campaign has been the use of our website www.eurokoalas.com, our Facebook group "Eurobodalla Koalas project" https://www.facebook.com/groups/187171881416765 and our Instagram account https://www.instagram.com/eurobodallakoalaproject/.

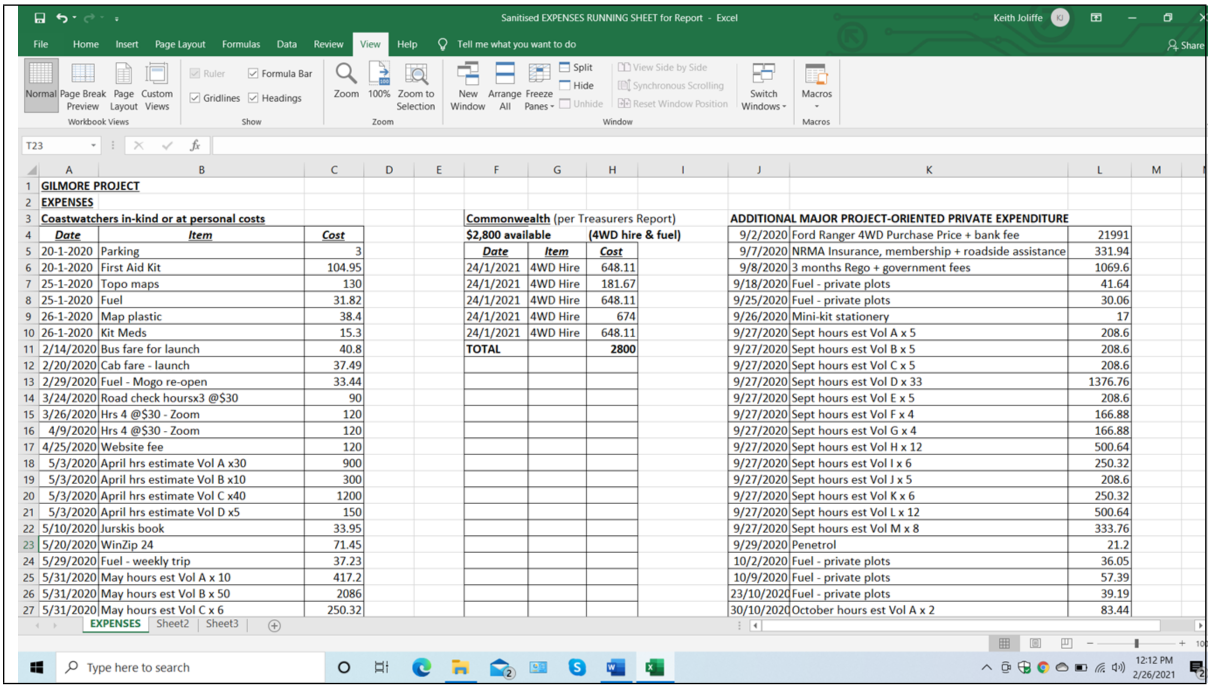
PROJECT EXPENDITURE

Through the *Gilmore Electorate Office*, the *Commonwealth Department of Industry, Science, Energy and Resources* provided **$2,800** for vehicle hire, with the expectation that the sponsoring organization *The Coastwatchers Association Inc* would match it in-kind.

The Commonwealth funds were disbursed to local providers as shown in the *Acquittal Spreadsheet* below (names and bank details removed).

Detail of volunteers' personal expenditure and in-kind support is also in the acquittal spreadsheet (names and bank details removed). This is a conservative estimate totaling at minimum **$43,446.66**. It demonstrates starkly the commitment made by volunteers and not-for-profit organizations when they conduct such projects and enter into arrangements with funding bodies.

Acquittal Spreadsheet



GILMORE PROJECT

EXPENSES

Coastwatchers in-kind or at personal costs

Date	Item	Cost
20-1-2020	Parking	3
20-1-2020	First Aid Kit	104.95
25-1-2020	Topo maps	130
25-1-2020	Fuel	31.82
26-1-2020	Map plastic	38.4
26-1-2020	Kit Meds	15.3
2/14/2020	Bus fare for launch	40.8
2/20/2020	Cab fare - launch	37.49
2/29/2020	Fuel - Mogo re-open	33.44
3/24/2020	Road check hoursx3 @$30	90
3/26/2020	Hrs 4 @$30 - Zoom	120
4/9/2020	Hrs 4 @$30 - Zoom	120
4/25/2020	Website fee	120
5/3/2020	April hrs estimate Vol A x30	900
5/3/2020	April hrs estimate Vol B x10	300
5/3/2020	April hrs estimate Vol C x40	1200
5/3/2020	April hrs estimate Vol D x5	150
5/10/2020	Jurskis book	33.95
5/20/2020	WinZip 24	71.45
5/29/2020	Fuel - weekly trip	37.23
5/31/2020	May hours est Vol A x 10	417.2
5/31/2020	May hours est Vol B x 50	2086
5/31/2020	May hours est Vol C x 6	250.32

Commonwealth (per Treasurers Report)

$2,800 available **(4WD hire & fuel)**

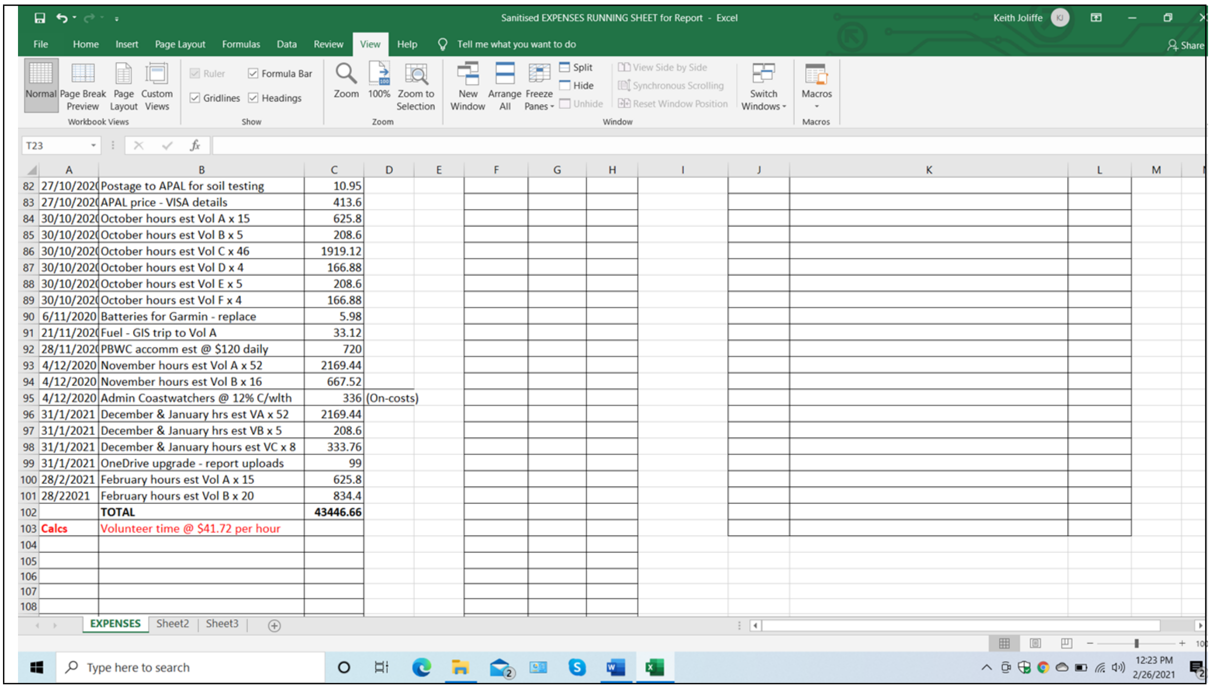
Date	Item	Cost
24/1/2021	4WD Hire	648.11
24/1/2021	4WD Hire	181.67
24/1/2021	4WD Hire	648.11
24/1/2021	4WD Hire	674
24/1/2021	4WD Hire	648.11
TOTAL		**2800**

ADDITIONAL MAJOR PROJECT-ORIENTED PRIVATE EXPENDITURE

9/2/2020	Ford Ranger 4WD Purchase Price + bank fee	21991
9/7/2020	NRMA Insurance, membership + roadside assistance	331.94
9/8/2020	3 months Rego + government fees	1069.6
9/18/2020	Fuel - private plots	41.64
9/25/2020	Fuel - private plots	30.06
9/26/2020	Mini-kit stationery	17
9/27/2020	Sept hours est Vol A x 5	208.6
9/27/2020	Sept hours est Vol B x 5	208.6
9/27/2020	Sept hours est Vol C x 5	208.6
9/27/2020	Sept hours est Vol D x 33	1376.76
9/27/2020	Sept hours est Vol E x 5	208.6
9/27/2020	Sept hours est Vol F x 4	166.88
9/27/2020	Sept hours est Vol G x 4	166.88
9/27/2020	Sept hours est Vol H x 12	500.64
9/27/2020	Sept hours est Vol I x 6	250.32
9/27/2020	Sept hours est Vol J x 5	208.6
9/27/2020	Sept hours est Vol K x 6	250.32
9/27/2020	Sept hours est Vol L x 12	500.64
9/27/2020	Sept hours est Vol M x 8	333.76
9/29/2020	Penetrol	21.2
10/2/2020	Fuel - private plots	36.05
10/9/2020	Fuel - private plots	57.39
23/10/2020	Fuel - private plots	39.19
30/10/2020	October hours est Vol A x 2	83.44

	A	B	C	J	K	L
28	5/31/2020	May hours est Vol D x 4	166.88	30/10/2020	October hours est Vol B x 5	208.6
29	5/31/2020	May hours est Vol E x 2	83.44	30/10/2020	October hours est Vol C x 2	83.44
30	5/31/2020	May hours est Vol F x 2	83.44	30/10/2020	October hours est Vol D x 48	2002.56
31	6/5/2020	Fuel - weekly trip	30.29	6/11/2020	Fuel - private plots	39.66
32	6/12/2020	Fuel - weekly trip	37.83	6/11/2020	75% of Printer Cartridges for Google Earth etc	61.48
33	6/12/2020	Batteries for GPS	6	#########	Fuel - private plots	80.03
34	6/12/2020	Costermans book for kit	43.7	4/12/2020	November hours est Vol A x 16	667.52
35	6/26/2020	Fuel - weekly trip	32.45	4/12/2020	November hours est Vol B x 8	333.76
36	7/1/2020	Pencils for kit	6	4/12/2020	November hours est Vol C x 5	208.6
37	7/1/2020	June hours est Vol A x 4	166.88	4/12/2020	November hours est Vol D x 3	125.16
38	7/1/2020	June hours est Vol B x 70	2920.4	1/1/2021	December hours est Vol A (school liaison) x 5	208.6
39	7/1/2020	June hours est Vol C x 10	417.2		**TOTAL**	**32327.12**
40	7/1/2020	June hours est Vol D x 20	834.4			
41	7/1/2020	June hours est Vol E x 10	417.2			
42	7/1/2020	June hours est Vol F x 10	417.2			
43	7/2/2020	Vol G vehicle cost - plot trip	100			
44	7/3/2020	BayPost digi subs	41			
45	7/3/2020	Fuel - weekly trip	19.26			
46	7/10/2020	Fuel - weekly trip	24.81			
47	7/21/2020	Hard Hats x6 @ 8.95 ea	53.7			
48	7/24/2020	Fuel - survey trip	28.48			
49	8/1/2020	July hours est Vol A x 3	125.16			
50	8/1/2020	July hours est Vol B x 82	3421.04			
51	8/1/2020	July hours est Vol C x 2	83.44			
52	8/1/2020	July survey hours Vol D x 8	333.76			
53	8/1/2020	July survey hours Vol E x 8	333.76			
54	8/1/2020	July hours est Vol F x 18	750.96			

	A	B	C
55	8/1/2020	July survey hours Vol G x 8	333.76
56	8/1/2020	July hours est Vol H x 48	2002.56
57	8/1/2020	July survey hours Vol I x 8	333.76
58	8/1/2020	July hours est Vol J x 1	41.72
59	8/1/2020	Flagging tape	15.75
60	8/7/2020	Fuel - survey trip	24.56
61	8/22/2020	Fuel - survey trip	25.56
62	8/27/2020	Timestamp app & fee	74.6
63	8/28/2020	Fuel - survey trip	30.19
64	8/28/2020	Pencils for kit	6
65	8/31/2020	Hrs 3.5@$41.72 - Zoom + writeup	146.02
66	9/2/2020	August hours est Vol A x 82	3421.04
67	9/2/2020	August hours est Vol B x 14	584.08
68	9/2/2020	August survey hours Vol C x 8	333.76
69	9/2/2020	August survey hours Vol D x 16	667.52
70	9/2/2020	August hours est Vol E x 30	1251.6
71	9/2/2020	August hours est Vol F x 20	834.4
72	9/2/2020	August survey hours Vol G x 8	333.76
73	9/2/2020	August hours est Vol H x 5	208.6
74	9/2/2020	August hours est Vol I x 1	41.72
75	9/2/2020	August hours est Vol J x 10	417.2
76	9/4/2020	Fuel - survey trip	34.25
77	9/27/2020	Sept hours est Vol A x 2	83.44
78	9/27/2020	Sept hours est Vol B x 30	1251.6
79	9/27/2020	Sept hours est Vol C x 10	417.2
80	9/27/2020	Sept hours est Vol D x 30	1251.6
81	16/10/202(	Fuel - survey trip	46.89



	A	B	C	D
82	27/10/202	Postage to APAL for soil testing	10.95	
83	27/10/202	APAL price - VISA details	413.6	
84	30/10/202	October hours est Vol A x 15	625.8	
85	30/10/202	October hours est Vol B x 5	208.6	
86	30/10/202	October hours est Vol C x 46	1919.12	
87	30/10/202	October hours est Vol D x 4	166.88	
88	30/10/202	October hours est Vol E x 5	208.6	
89	30/10/202	October hours est Vol F x 4	166.88	
90	6/11/2020	Batteries for Garmin - replace	5.98	
91	21/11/202	Fuel - GIS trip to Vol A	33.12	
92	28/11/202	PBWC accomm est @ $120 daily	720	
93	4/12/2020	November hours est Vol A x 52	2169.44	
94	4/12/2020	November hours est Vol B x 16	667.52	
95	4/12/2020	Admin Coastwatchers @ 12% C/wlth	336	(On-costs)
96	31/1/2021	December & January hrs est VA x 52	2169.44	
97	31/1/2021	December & January hrs est VB x 5	208.6	
98	31/1/2021	December & January hours est VC x 8	333.76	
99	31/1/2021	OneDrive upgrade - report uploads	99	
100	28/2/2021	February hours est Vol A x 15	625.8	
101	28/22021	February hours est Vol B x 20	834.4	
102		**TOTAL**	**43446.66**	
103	Calcs	Volunteer time @ $41.72 per hour		

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Thanks

Too many to list are the numerous individuals, volunteers, researchers, agencies and other community, environmental and animal welfare groups who made the Gilmore Electorate project possible and contributed to this report's peer review.

Fiona Phillips MP Member for Gilmore, the Commonwealth Department of Industry, Science, Energy and Resources, and The Coastwatchers Association Inc were the formal partners for funding purposes.

Forestry Corporation NSW Southern Region and National Parks and Wildlife Service South Coast Branch hosted the fieldwork.

Pebbly Beach Wildlife Centre provided accommodation and office space.

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