NSW GOVERNMENT

Framework for the spatial prioritisation of koala conservation actions in NSW

Saving our Species Iconic Koala Project

A report prepared for the Office of Environment and Heritage
by Brendan Rennison and Mark Fisher

Cover photo: Koala (*Phascolarctos cinereus*). John Turbill/OEH

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Introduction

Background

Saving our Species (SoS) is a statewide program of the NSW Government that aims to secure threatened plants and animals in the wild in New South Wales. Under SoS, the koala (*Phascolarctos cinereus*) has been identified as one of six iconic NSW species that are important socially, culturally and economically, and which the community expects to be effectively managed and protected.

The Saving our Species Iconic Koala Project aims to secure the koala in the wild in New South Wales for 100 years by:

- reducing critical threats to the species
- ensuring adequate protection, management and restoration of koala habitat
- maintaining healthy breeding populations of koalas throughout their current range.

Between 2017 and 2021, the SoS Iconic Koala Project is coordinating koala conservation actions across New South Wales and providing seed funding for priority actions. Input from experts and the community is being combined with scientific analysis to identify those conservation actions likely to have the most significant outcomes.

Data-driven spatial analysis is needed to support koala conservation

The guiding document for the SoS Iconic Koala Project (OEH 2016a) clearly states the need for koala conservation actions to use data-driven spatial analysis to determine areas of significance, with priority investment for 2017–18 to include:

> *Further spatial analysis, identifying areas of regional and local koala significance for future prioritisation of conservation actions.*

Recommendations made in the *Report of the Independent Review into the Decline of Koala Populations in Key Areas of NSW* (NSW Chief Scientist & Engineer 2016) include:

- **Recommendation 1** – *That Government adopt a whole-of-government koala strategy for NSW with the objective of stabilising and then starting to increase koala numbers.*

  The strategy should [among other things]:

  - *identify key koala populations and management areas which have the potential for long-term recovery and viability*
  - *identify priority threats to key koala populations at the population scale, through mapping and establishing threat hierarchies.*

- **Recommendation 7** – *That Government agencies identify priority areas of land across tenures to target for koala conservation management and threat mitigation.*

In response to the above priority investment and recommendations of the Independent Review, a project has been funded under the SoS Iconic Koala Project with the aim of providing support and strategic direction to future priorities in conservation actions for the koala. It is one of many projects designed to support data-driven (evidence-based) decision-making for koala conservation.

Identifying areas of koala occupancy at risk of decline and important threatening processes

The impetus for the project has also stemmed from a growing body of evidence of declining koala populations in New South Wales. One of the most recent significant studies of east coast koala populations (Adams-Hosking et al. 2016) estimates koala populations in almost every bioregion in the state as being in significant decline. Table 1 shows many figures from the Adams-Hosking et al. study, including population estimates, trend status (declining, stable or increasing) and several records analyses. The overall trend of both the expert elicitation data (Adams-Hosking et al. 2016) and the records trend data (where available) points to an almost universal decline of koalas across New South Wales in recent years. The only bioregion with convincing evidence of a stable population from both expert elicitation and records trend data is the New England Tablelands.

While the bioregional analysis illustrated in Table 1 provides a useful overview of statewide trends, it has been observed by several studies (Scotts 2013, DECCW 2010a) that a more complex pattern of stable source koala populations and declining (sink) populations emerges within bioregions. The scale of the assessment conducted under this SoS-funded project has been designed to provide a statewide assessment of the areas of regional significance for koalas in New South Wales.

This project uses the concepts of *resilience* and *security* at a regional scale and *functional habitat* at an area scale to identify areas of koala occupancy which are at risk of decline. It provides an analysis of the landscape values important to koalas and threats to those values.

Drawing from these recommendations, the project includes three broad components, which are presented in separate reports:

1. Audit of Statewide Spatial Datasets (Rennison 2017a)
2. Assessment of the Current Reservation Systems and Protection of Koalas within the Bioregional Areas of NSW – includes a trial assessment of priority areas for acquisition in the South-East Highlands Bioregion (Rennison 2017b)
3. Development of a Framework for the Spatial Prioritisation of Koala Conservation Actions in NSW (this report).

Relationship with other koala-related conservation programs

This project has been funded under the SoS Iconic Koala Project, however there are several program streams within and outside of the Office of Environment and Heritage which are operating concurrently and have similar objectives and/or data requirements. These are outlined below.

NSW Koala Strategy

The NSW Government is implementing a NSW Koala Strategy to stabilise and then start to increase koala numbers. The recommendations of the report that guided the establishment of the NSW Koala Strategy include the identification of land across tenures to target for conservation management and threat mitigation.

This project provides a set of tools which are suitable to assist in the strategic prioritisation of conservation management programs. The identification of key koala population areas at statewide and regional scales and the associated measures of security, functional habitat and resilience, provide a useful framework for more detailed analysis and actions at the local scale.

NSW National Parks and Wildlife Service Acquisition Program

One pillar of the NSW Koala Strategy is an initiative to assist in the long-term protection of priority koala habitat. The NSW Government has allocated $20 million over five years to purchase and conserve private land to protect priority koala habitat (OEH 2018b). These purchases are to be made in line with National Parks and Wildlife Service (NPWS) acquisition criteria, with a focus on koala habitat and occupancy.

This project provides a set of tools which are suitable for applying in a decision support framework to assess potential properties for addition to the reserve system.

Biodiversity Conservation Trust

The NSW Biodiversity Conservation Trust (BCT) works in partnership with landholders to establish private land conservation agreements to conserve and manage high-value biodiversity on private land.

This project provides a set of tools that can contribute to the priority investment areas (e.g. core area mapping) identified by the BCT, including areas of identified high resilience, low security and high connectivity value.

Table 1 Koala populations across NSW IBRA regions

IBRA name	Population estimate (Adams-Hosking et al. 2016)	Status (stable, declining, sharply declining) from Adams-Hosking et al. 2016	Observations since 2011 (current generation)	Koala observations as a proportion of all arboreal observations (as a measure of survey effort)	Records analysis Stable or declining (since previous generation/s)	Overall trend
Brigalow Belt South and Nandewar	11,133	Declining (–35%)	292	11%	Overall decline over analysis period	Declining
Cobar Peneplain and Riverina	2,354	Declining – stable (–9%)	2	15%	Insufficient data	Declining – stable
Darling Riverine Plains	964	Declining (–34%)	2	25%	Insufficient data	Declining
Mulga Lands	711	Declining (–31%)	0	N/A	Insufficient data	Declining
Murray Darling Depression	55	Declining – stable (–12%)	0	N/A	Insufficient data	Declining – stable
New England Tablelands	2,771	Stable – increasing (+6%)	79	1%	Slight decline over analysis period	Stable
NSW North Coast	8,367	Declining (–50%)	2,010	21%	Overall decline over analysis period	Declining
NSW South Western Slopes	2,310	Declining (–23%)	3	0%	Overall decline over analysis period	Declining
South East Corner	2,768	Declining (–46%)	213	4%	Declining over last generation, but stable overall	Declining – stable
South Eastern Highlands	1,363	Declining (–19%)	323	5%	Overall decline over analysis period	Declining
South Eastern Queensland (QLD figures)	15,821	Declining (–51%)	1,801	51%	Increase over recorded period*	Declining
Sydney Basin	5,667	Declining – stable (–4%)	406	5%	Moderate decline over survey period	Declining – stable

* Increase in recorded occurrence of koalas in South East Queensland over past three generations associated with increased focus on koala management and accompanying survey effort including CKPoM SAT data and Dan Lunney's Community Wildlife Survey.

Establishing a framework for prioritising koala conservation actions

A central challenge of the SoS Iconic Koala Project is to ensure that threats to koala populations in New South Wales are effectively and efficiently managed and that management efforts are targeted at the most significant threats.

This project aims to prioritise conservation action and investment by targeting areas known to be occupied by significant koala populations (OEH 2016a). A spatial prioritisation framework has therefore been developed to help guide the implementation of the most cost-effective actions.

Six broad steps have been identified in the process for prioritisation of koala conservation actions in New South Wales. The process loosely follows a traditional risk assessment design, with threats considered in the context of their likelihood of occurrence and potential for consequences on the values considered important for securing koala areas into the future.

Step 1 identifies the main areas of New South Wales with significant populations of koalas, while Step 2 identifies key threats to those populations. Step 3 examines the values which are supporting the persistence of koalas in these areas and Step 4 looks at risks to their persistence. Future 'resilience' for koala areas is predicted in Step 5, based on the level of risk that the values are exposed to and, together with the resilience class, the threat risk classes are used in Step 6 to identify the most appropriate management strategies offered by the action toolbox[1] to mitigate the threats considered to be important for each koala population.

Figure 1 sets out the six steps followed in establishing the spatial prioritisation framework and Figure 2 represents this framework in terms of the conceptual flow of the data analysis and outputs tools for prioritisation of koala areas. The six steps are outlined in detail in the next chapter.

[1] Species in the landscape management stream of SoS each have an 'action toolbox' in the SoS database. A species' toolbox defines specific, practical and meaningful actions for controlling critical threats and securing populations on the ground (OEH 2015b).

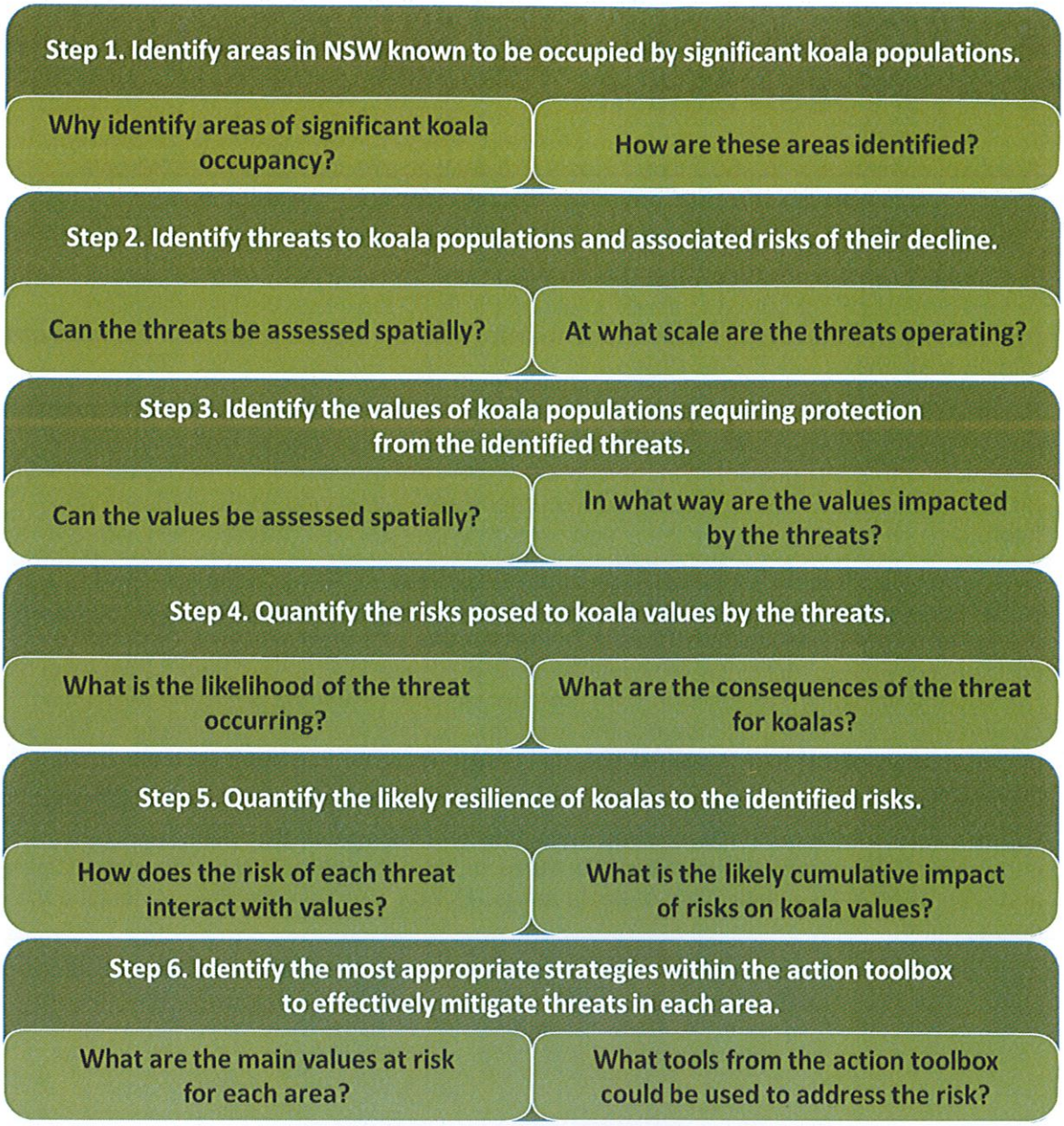


Figure 1 Process steps for establishing the action prioritisation framework

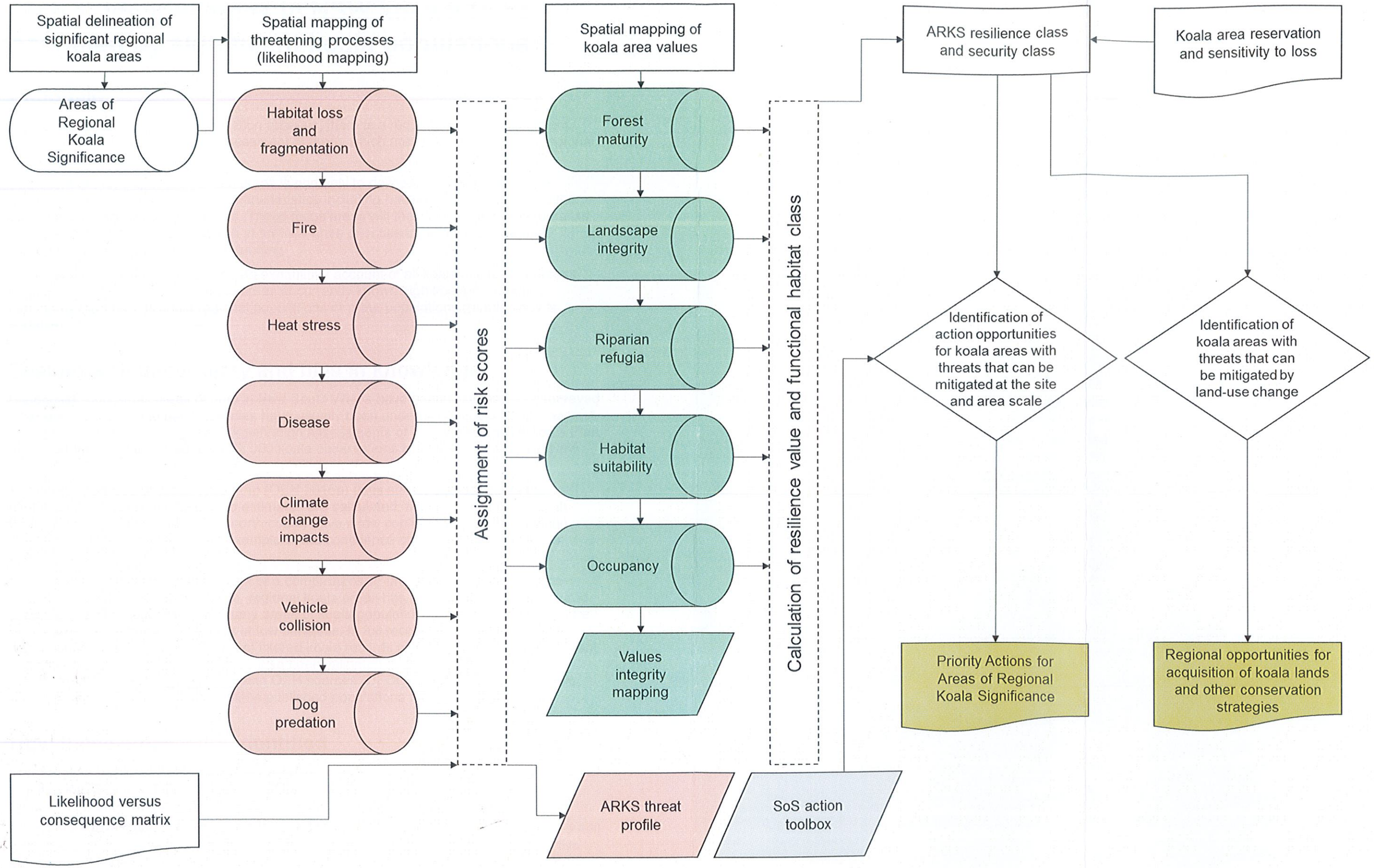


Figure 2 **Process diagram for identifying actions for Areas of Regional Koala Significance**

Step 1: Identify areas in NSW known to be occupied by significant koala populations

Rationale

As a basis for a NSW-wide prioritisation analysis, there is a requirement for a consistent, tenure-blind and current spatial assessment of areas which are known to have high regional significance for koalas.

The intent of these spatially defined areas is primarily to delineate focus areas for the analysis of resilience and security characteristics including habitat values and risks to the persistence of koalas in these areas. These focus areas will then be used for more detailed analysis of threats and values which in turn will drive priorities for koala management strategies, conservation action and funding.

These areas are not designed to be an exhaustive account of all koala occupancy across New South Wales, but rather define areas of currently known high koala occupancy, commonly regarded as koala regional populations or meta-populations (terminology is variable).

Dealing with uncertainty and bias in knowledge

Historically, only small areas of land in New South Wales have been systematically surveyed for koala activity. These habitat studies have usually been undertaken as part of pre-harvest surveys (Forests NSW), regional conservation assessments or a Comprehensive Koala Plan of Management. Since 1990, over 22,000 koala observations have been recorded in New South Wales.

The koala likelihood of occurrence map (OEH 2015a) uses survey effort to score the confidence with which the likelihood estimates are calculated. Most areas of New South Wales (including large parts of the north coast) have a low confidence, albeit presenting likelihood of koala occupancy. An example of the confidence of occurrence mapping is shown in Figure 3.

While the risk associated with the lack of a comprehensive unbiased dataset cannot be eliminated, the analysis of statewide, regional koala areas has been consciously structured to be inclusive in recognition that many areas of koala populations in New South Wales are poorly sampled and may also occur at low densities. In full recognition of data bias, it is worth noting that 92% (over 20,000) of filtered koala records occur within mapped significant koala areas. The identified areas have also been validated against available published (Scotts 2013, Paull & Hughes 2016) and OEH sources (DECCW 2010a). Where possible and appropriate, equivalencies to these published populations have been provided.

How these areas were identified

The Areas of Regional Koala Significance (ARKS) were identified using analysis of koala observation densities, followed by spatial filtering of non-habitat features, incorporating barrier information where available.

A total of 48 ARKS were identified, with the smallest being South West Rocks, at around 400 hectares, and the largest being Bungonia (Illawarra) at 353,000 hectares (made up of five sub-areas). Altogether, 4,195,549 hectares (~42,000 square kilometres), or around 5% of New South Wales is mapped as being of significance for koalas.

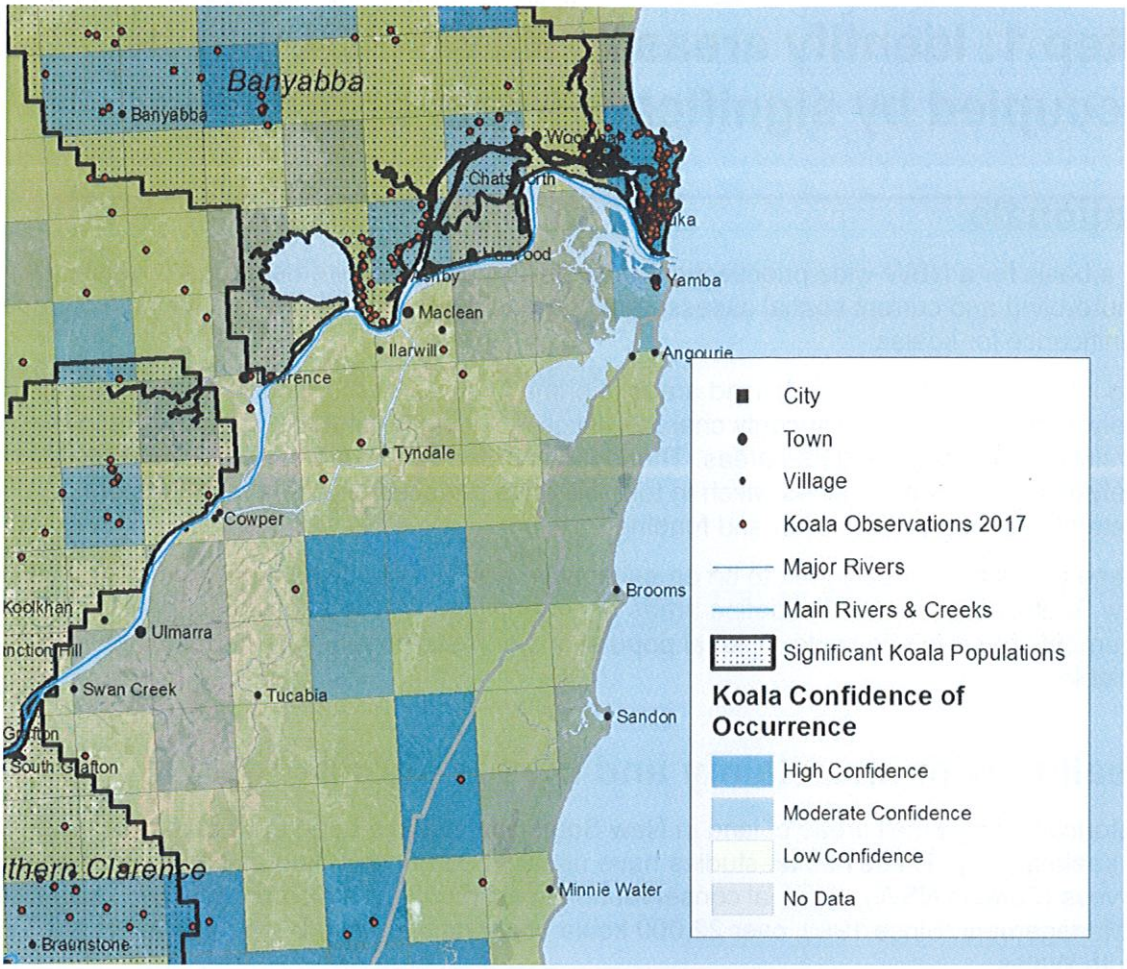


Figure 3 Confidence of likelihood of koala occupancy in Mid North Coast New South Wales (Predavec 2016)

Density analysis

A kernel density analysis (ArcGIS toolbox) was used to analyse a minimum threshold of observations of koala occurrence across the NSW landscape. As a basis for this metric, a baseline search threshold of 10 km was adopted, reflecting what is generally accepted as the maximum seasonal movement of koalas across the landscape. For example, koalas studied in south-east Queensland moved on average 3.5 km (and up to 10.6 km) in their first breeding season (Dique et al. 2003a). Absence data for koala observations is restricted to SAT (scat search) surveys, which are largely associated with Comprehensive Koala Plans of Management. Absence (nil activity) data has therefore not been included in the analysis.

A very low threshold was used to set the minimum occupancy density for inclusion as a candidate area of significance. This approach was used to alleviate concerns that low density koala populations or populations with inadequate survey may be excluded. While the limitations of current data will inevitably lead to inadequacies in the definition of areas of regional significance, it is hoped that a more inclusive analysis can minimise the effects of data deficiency. The final density threshold for candidate areas was set at 0.06 records per hectare, roughly equating to one observation per home range for medium density koala populations. Figure 4 shows an example of the density mapping output and the final koala area boundary with filters applied.

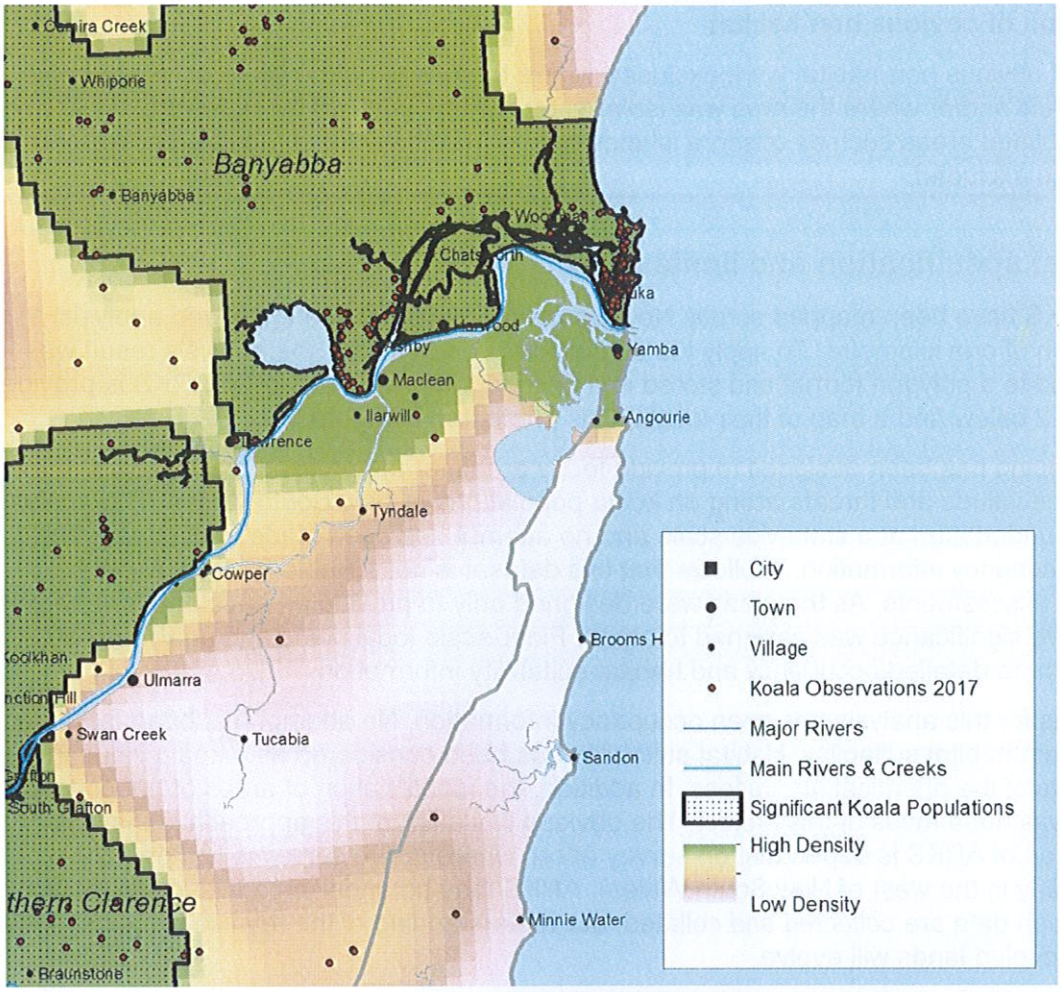


Figure 4 **Analysis of koala density in Mid North Coast New South Wales – Banyabba regionally significant area**

Application of filters

Several spatial and size criteria filters were applied to refine and consolidate regionally significant areas. These criteria have been designed to exclude likely non-habitat areas and consolidate likely habitat areas (where survey density is limited).

Minimum threshold for areas of significance

A minimum threshold for area of 100 hectares was applied for areas of regional significance. This threshold was applied to exclude scattered and isolated koala occurrences, usually with limited evidence of continued (resident) populations.

Application of barriers to koala movement to split areas of regional significance

Known barriers to koala movement were applied and reviewed for effectiveness. Upper North Coast barriers (Millage 2016), Mid North Coast barriers (Scotts 2013) and Lower North Coast barriers (Kendall 2016) were initially applied and then reviewed for accuracy and comprehensiveness. Categories of barrier included:

- Pacific Highway sections (excluding sections where underpasses have been created to enable movement)
- riparian areas which form a barrier (major rivers with open water free of vegetation)
- rainforest areas
- altitudinal barriers (escarpment).

Exclusion of obvious non-habitat

Areas of obvious non-habitat were excluded where there was no evidence of recent koala occurrence and/or where the area was isolated by barriers such as those referred to above. Other isolated areas such as offshore islands or river islands with no recorded occurrence were also excluded.

Product specification and limitations

The ARKS have been mapped across New South Wales using an original grid analysis resolution of one kilometre. To apply the spatial filters and checks, the analysis result was converted to a polygon format and stored in a file geodatabase. A list of all ARKS is provided in Table 2 below and a map of their locations is presented in Figure 5.

The mapping has been designed to provide focus areas for the profiling and analysis of the landscape values and threats acting on koala populations in New South Wales. The analysis is being undertaken at a statewide scale and no attempt has been made to delineate fine-scale occupancy information. It follows that this dataset is not suitable for local scale / property assessments. As the areas were designed only to provide an envelope for analysis, no relative significance was assigned to areas. Finer-scale local plans and analyses can provide more detailed occupancy and habitat suitability information.

The basis for this analysis has been occupancy information. No attempt has been made to incorporate habitat suitability. Habitat suitability has been considered as a koala value in later parts of the prioritisation process. In addition, the identification of areas of unoccupied habitat was not a focus of this project. The obvious limitation of this approach is that the recognition of ARKS is dependent on survey effort; where active survey is limited (particularly in the west of New South Wales), ARKS may be under-recognised. As more observation data are collected and collated, our understanding of the relative significance of koala occupied lands will evolve.

Table 2 List of ARKS with their basic characteristics. Also refer to Figure 5.

No.	Arks name	Region	Total area (ha)	Resilience	Security
1	Armidale	New England Tablelands	70,509	Low	Low
2	Banyabba	South Eastern Queensland	141,774	Moderate	Low
3	Barrington	NSW North Coast	166,660	Moderate	Low
4	Belmore River	NSW North Coast	48,027	Moderate	Low
5	Blaxland	Sydney Basin	24,800	Moderate	Low
6	Brisbane Water NP	Sydney Basin	12,817	High	High
7	Bungonia	Sydney Basin	353,546	Moderate	Moderate
8	Clouds Creek	NSW North Coast	115,417	High	Moderate
9	Coffs Harbour – North Bellingen	NSW North Coast	190,531	Moderate	Moderate
10	Comboyne	NSW North Coast	220,554	Moderate	Moderate
11	Crowdy Bay	NSW North Coast	17,494	High	High
12	Far north-east	South Eastern Queensland	20,827	Low	Moderate
13	Far north-east Hinterland	South Eastern Queensland	339,862	Moderate	Moderate
14	Gibraltar Range	NSW North Coast	9,206	High	High

No.	Arks name	Region	Total area (ha)	Resilience	Security
15	Girard – Ewingar	NSW North Coast	34,110	High	Moderate
16	Gunnedah	Brigalow Belt South	271,808	Low	Moderate
17	Hawks Nest	NSW North Coast	2,563	High	Low
18	Inverell	Nandewar	35,407	Low	Low
19	Karuah – Myall Lakes	NSW North Coast	18,817	Moderate	Moderate
20	Khappinghat	NSW North Coast	18,784	Moderate	Moderate
21	Killarney	Brigalow Belt South	16,507	Low	Low
22	Kiwarrak	NSW North Coast	34,911	Moderate	Moderate
23	Kwiambal NP	Nandewar	5,703	Moderate	Moderate
24	Lower Hunter	Sydney Basin	114,915	High	Moderate
25	Moree	Brigalow Belt South	23,598	Low	Low
26	Mt Pikapene	South Eastern Queensland	93,196	Moderate	Moderate
27	Murrah	South East Corner	82,402	High	High
28	Murray Valley	Riverina	10,491	Low	Moderate
29	Narrandera	NSW South Western Slopes	31,909	Low	Low
30	North Macleay – Nambucca	NSW North Coast	242,233	Moderate	Moderate
31	Nowendoc	New England Tablelands	42,505	Moderate	Moderate
32	Nullica	South East Corner	51,807	High	High
33	Numeralla	South East Highlands	116,699	High	Moderate
34	Pilliga	Brigalow Belt South	288,100	Low	High
35	Port Macquarie	NSW North Coast	25,140	Moderate	Moderate
36	Port Stephens	NSW North Coast	49,322	Moderate	Moderate
37	Queen Charlottes Creek	South East Highlands	73,210	Low	Low
38	Severn River NR	New England Tablelands	12,102	High	High
39	Southern Clarence	South Eastern Queensland	63,164	Low	Moderate
40	Tweed Coast	South Eastern Queensland	15,634	Low	Low
41	Wallingat NP	NSW North Coast	37,798	High	Moderate
42	Wang Wauk SF	NSW North Coast	174,864	Moderate	Moderate
43	Wilson River	NSW North Coast	112,432	Moderate	Moderate
44	Wollemi NP	Sydney Basin	100,094	High	High
45	Woodenbong	South Eastern Queensland	175,702	Moderate	Moderate
46	North Grafton	South Eastern Queensland	59,755	Low	Moderate
47	Broadwater	South Eastern Queensland	13,913	Moderate	Moderate
48	Tweed Ranges	South Eastern Queensland	32,043	Moderate	Moderate

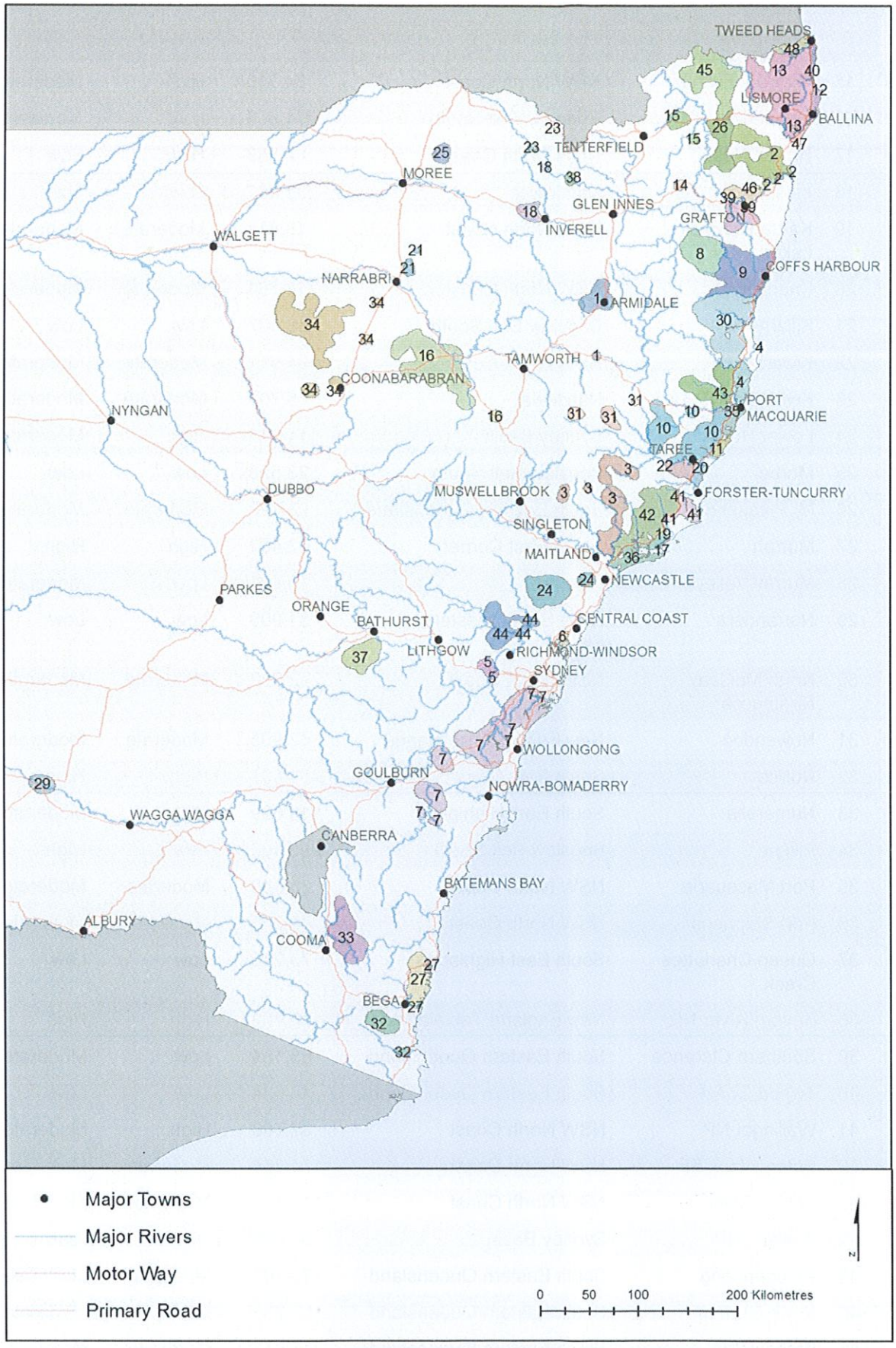


Figure 5 **Areas of Regional Koala Significance in New South Wales. Also refer to Table 2 for ARKS name and general information.**

Step 2: Identify threats to koala populations and associated risks of their decline

Rationale

Recent studies including an unpublished report to the NSW Office of Environment and Heritage (Smith, Lunney and Moon 2016) identified a set of major threat groups which were described and ranked in terms of risk across bioregions of eastern Australia. A total of 14 threat groups were assigned, of which the majority were thought to be relevant to New South Wales. A panel of koala experts was asked to rank the past and future expected intensity of threats to koalas on a bioregional basis, from being absent, to having a significant impact. The study predicted significant and increasing threats across several threat groups including those stemming directly from human activities (e.g. mining) and climatic threats (e.g. drought).

The threat groups identified by this study and others, including the Chief Scientist & Engineer's report (NSW Chief Scientist & Engineer 2016), have been used as a basis for the identification of threats and the development of strategies to spatially define and quantify their influence on koala occupancy and habitat values.

Scale of threat identification

The processes which drive threats to koala populations have a range of spatial scales, ranging from continental (e.g. climatic influences) to site level (e.g. vehicle strike and habitat loss). The recognition of the influence of scale when addressing threatening processes is an important consideration, as it helps to direct the kinds of mitigating actions which may be appropriate.

Site scale threats are those which can be observed and measured at a site or property scale. Mitigation strategies invariably require a site scale solution.

Area scale threats are often less measurable, but their effect is more obvious at an area (or regional) scale. Mitigation strategies often require coordinated programs (e.g. prescribed burning plans including ecological burning undertaken by groups including Firesticks[2] (Northern Star 2016)).

State scale threats are those which are difficult to observe or measure, even at the regional scale (such as drought or climate change). Mitigation strategies often involve state coordinated programs and research (e.g. climate change adaptation through AdaptNSW programs and resources) (OEH 2018a).

Outline of threat types

Nine distinct threat groupings have been identified for the purposes of this study to provide a framework for the spatial assessment of these threats across population areas in New South Wales. These threat groups have been drawn from a recent study undertaken for OEH (Smith, Lunney & Moon 2016) which outlined 14 separate threat groups across eastern Australia. The most relevant threat groups to New South Wales were selected and developed to form the basis of this study.

[2] An initiative that seeks to use burning practices developed by Aboriginal people to create ecologically resilient landscapes via communication pathways, education and on-ground land management.

Table 3 below outlines the threat definitions, the scale of process at which each threat operates and the range of values which would be expected to be impacted directly.

Table 3 Threat definitions for identified threats which can be prioritised using spatial mapping

Threat name	Threat definition	Reference	Scale of process	Values at risk
Habitat loss, fragmentation and degradation	The process of modification of ecosystems in such a way that reduces their capacity to support native species. This typically includes the loss, fragmentation and/or degradation of habitat. Fragmentation can be defined as the breaking apart of habitat, reducing the overall size of habitat and increasing the distance between patches such that the ability of fauna to move between them is reduced (Andrén 1994). Habitat degradation is where the quality of habitat is reduced over time. These three related processes may be caused by both natural and anthropogenic processes (Smith, Lunney & Moon 2016). For the purposes of the spatial prioritisation, urbanisation and mining development have been incorporated into this category.	SPRAT (DEE 2017) DECC 2008 Smith, Lunney, Moon 2016 OEH 2016a	Site	Forest maturity Landscape linkage Habitat suitability Refugia
Urbanisation (assessed as part of the above threats)	Urbanisation is the large-scale or incremental conversion of an area of land from a more natural state to dwellings and associated structures for the human population arising from expansion of towns and cities (Smith, Lunney & Moon 2016).	SPRAT (DEE 2017) Smith, Lunney, Moon 2016 DECC 2008 OEH 2016a	Site	Forest maturity Landscape linkage Habitat suitability Refugia
Collisions with motor vehicles	Collisions between koalas and motor vehicles are a widely documented regular occurrence in Australia. Busy roads in close proximity to occupied koala habitat are often a focus of concern by local councils and carer groups.	SPRAT (DEE 2017) Smith, Lunney, Moon 2016 DECC 2008 OEH 2016a	Site	Occupancy
Predation by wild or domestic dogs	Dog attacks on koalas are a significant cause of koala death and injury (DECC 2008). They are regarded as a threat across NSW, but particularly in populations in and around rural residential and peri-urban areas.	SPRAT (DEE 2017) Smith, Lunney, Moon 2016 DECC 2008 OEH 2016a	Site or area	Occupancy

Threat name	Threat definition	Reference	Scale of process	Values at risk
Wildfire and intense prescribed burns	Wildfire is a common and widespread natural and anthropogenic process in the eucalypt forests of Australia. The devastating effects of past intense wildfires on koala populations has been well documented. Prescribed fuel reduction burns carried out in the shoulder seasons may also cause canopy scorch, resulting in habitat loss and injury to koalas.	Smith, Lunney, Moon 2016 DECC 2008 OEH 2016a	Area	Occupancy Forest maturity
Drought	Drought (periods of abnormally low rainfall) is associated with koala decline in large areas of NSW, particularly in the west. Recent drought conditions in the Gunnedah area have caused koala populations to crash (Adams-Hosking & McAlpine 2017). Koalas are susceptible to climatic extremes, particularly heatwaves and droughts, which also affect the quality of nutrients and moisture available in their diet (Cork & Braithwaite 1996; Moore & Foley 2005).	SPRAT (DEE 2017) Smith, Lunney, Moon 2016 DECC 2008 OEH 2016a	Area or state	Occupancy
Heatwave	Heatwaves are defined as 'three days or more of high maximum and minimum temperatures that are unusual for that location' (Bureau of Meteorology 2018).	SPRAT (DEE 2017) Smith, Lunney, Moon 2016 DECC 2008 OEH 2016a	Area or state	Occupancy
Disease	Wild populations of koalas in NSW carry a number of pathogens that cause disease symptoms. The most common cause of disease in NSW is from the Chlamydiosis bacterium, which causes infertility, blindness and death (Polkinghorne et al. 2013).	SPRAT (DEE 2017) Smith, Lunney, Moon 2016 DECC 2008 OEH 2016a	Area	Occupancy
Reduction in suitability of habitat from the effects of climate change	The effects of anthropogenic climate change are expected to interact with a number of other threats to cause a significant, possibly severe, reduction in the suitability of habitat across NSW.	SPRAT (DEE 2017) Smith, Lunney, Moon 2016 DECC 2008 OEH 2016a	Area or state	Forest maturity Landscape linkage Habitat suitability Refugia

Mapping threatening processes across the landscape

Representing the spatial distribution of threatening processes across the landscape has been routinely undertaken in New South Wales over the last 20 years as part of regional conservation assessments (e.g. DECCW 2010b, DEC 2004). When appropriately used, mapping of threat risk can make a valuable contribution to the management of conservation values. The scale of determination of threat processes is integral both to strategies for mapping risk and interpreting that risk in a management framework.

Table 4 below summarises each of the threat groups by the mapping strategy applied, the estimated scale of determination (from the source data), then logically the confidence with which any determination of the accuracy of that assessment can be made. It is important to note that all analysis datasets have been rescaled to 500 metre grids for the purposes of analysis consistency. The scale of determination, therefore, is based on the spatial integrity of the source data. A detailed profile of each threat class is provided in Appendix D.

Table 4 Threat groups, mapping strategy, scale of determination and confidence

Threat name	Threat mapping strategy	Scale of determination	Confidence of determination

Habitat loss, fragmentation and degradation	Assignment of risk likelihood classes to recognised contributing landscape processes. These processes include:
	• clearing of native vegetation
	  ○ clearing history
	  ○ land capability and suitability
	• timber harvesting
	  ○ state forest FMZ
	  ○ private native forestry activity
	• mining exploration
	  ○ active mining leases
	  ○ exploration areas
	• land use
	  ○ land zoning and tenure.
		Site	Moderate

Urbanisation (assessed as part of habitat loss, fragmentation and degradation)	Assignment of risk classes to land identified for urban, commercial or industrial expansion, including: • areas identified by the recently released regional plans as new release or investigation • areas currently zoned as urban, industrial, commercial or large lot residential.	Site	High
Collisions with motor vehicles	Data collected from the BioNet database often contains roadkill or road injury information which can be used to develop risk classes for hotspots of high mortality and road types which have high rates of collision. Habitats in proximity to roads are assigned risk according to the risk score of the road category.	Site	Low

Threat name	Threat mapping strategy	Scale of determination	Confidence of determination
Predation by wild or domestic dogs	Spatial analysis of BioNet data recorded as a dog attack or near miss showed that the bulk of interactions (80%) were clustered within 200 m of urban or rural residential zoned land. These areas are categorised as high risk. Rural lands are still of moderate risk, with the remaining 20% of attacks occurring within 5 km of a dwelling.	Area	Low
Wildfire and intense prescribed burns	Fire intensity is closely associated with fuel loads. The NSW RFS modelled fuel loads for NSW using the Phoenix Rapidfire decision support tool which considers time since fire, vegetation type and fuel accumulation parameters.	Area	Moderate
Drought (not mapped)	Drought risk modelling is not currently available for NSW. No suitable surrogates for this risk category have been located.	Area or state	N/A
Heatwave	The NARCliM climate modelling project provides a range of predictive models of risk for current and future high maximum temperature (35+°C) frequency. Using these as a surrogate for heatwave likelihood, heatwave risk classes have been assigned.	Area or state	Moderate
Disease	Wildlife rehabilitation carer data, collected and processed by OEH from a range of community groups throughout NSW, has recorded rates of disease occurrence throughout koala populations in NSW (by postcode). Although not spatially explicit, this data provides a regional indication of relative risk for koala populations.	Area	Moderate
Reduction in suitability of habitat from the effects of climate change	Modelled data provided by the University of Melbourne maps relative likelihood of decline in habitat suitability for the koala across eastern Australia. Modelled suitability compares current period suitability with 2060–2079. Risk classes are assigned from the relative decline in modelled habitat.	Area or state	Low

Step 3: Identify the values of koala populations in New South Wales requiring protection from the identified threats

Rationale

Available literature on koalas identifies a range of landscape values which are important for the persistence of koala populations. Spatial identification of how these values are distributed across the landscape is an important step in assessing the level of threat that they may be exposed to by threatening processes identified in Step 2 (Identification of threats to koala populations).

A value profile of each ARKS will help build a picture of the resilience of that population to the threats operating in that landscape. This section identifies koala landscape values as identified by available data across New South Wales.

Scale of value identification

The spatial identification of koala values across the NSW landscape has been undertaken to be consistent with the threats assessment. As with the threats mapping, the values mapping has been derived using a collation of datasets from a variety of spatial scales ranging from extant vegetation (5 m raster) through to koala likelihood of occurrence (10 km grid in the west). Details of how each dataset has been included and resampled (where appropriate) are included under Step 4 below.

Outline of value types

Five value groups have been identified by this process which have some capacity for spatial recognition and mapping.

The spatial scale and reliability of mapping for these values is variable. The confidence of each value estimate needs to be accounted for in the assessment process. As with threat mapping, the scale of determination for each of the value mapping datasets is reflected in the final confidence assigned.

Table 5 below summarises each of the values for assessment, their scale of determination and the assigned confidence class. A detailed profile of each value class is provided in Appendix D.

Table 5 Threat definitions for identified threats that can be prioritised using spatial mapping

Value name	Value definition and analysis strategy	Reference	Scale of determination	Confidence of determination
Forest maturity	The structure of the forest canopy has been demonstrated to be linked to preference by koalas, with usage by koalas most common in trees of mature and senescent growth stages (over 30 cm diameter at breast height). Landsat TM vegetation change data since 1988 has been used to estimate regrowth forest extent. Forest not identified as regrowth or cleared is assumed to be mature. Higher value is given to mixed age and mature forest.	Smith 2004	Area	Low
Habitat connectivity and integrity	The distribution of habitat as measured by patch size has been found to be an important measure of occupancy by koalas. Vegetated linkage areas are important for koalas to survive. Where dispersal and recruitment are impeded by barriers such as open areas and roads, koala populations would be expected to decline (DECC 2008). Native woody vegetation was analysed for patch size and classified according to recognised important size thresholds, with larger patches considered of higher value.	DECC 2008	Site	High
Habitat suitability	The current SEPP44[3] defines potential habitat as vegetation communities with greater or equal to 15% canopy composition of koala feed trees. Vegetation classes of NSW were reviewed for feed tree likelihood (class descriptions are outlined in Keith 2004). Habitat suitability classes were assigned to each vegetation class.	DoP 1995 DECC 2008	Area	Moderate

[3] State Environmental Planning Policy (SEPP) 44 – Koala Habitat Protection

Value name	Value definition and analysis strategy	Reference	Scale of determination	Confidence of determination
Refugia	Access to permanent water in times of drought and heat stress is considered an important landscape feature. Mapping of permanent water across NSW has been undertaken with relative precision within the NSW Digital Terrain Database (DTDB) which denotes feature types (perennial versus ephemeral) and natural versus man-made. Patches of vegetation contiguous with perennial streams have been mapped. Large patches of habitat with access to water are valued highest.	DEE 2017 Crowther et al. 2014	Site	High
Occupancy	Likelihood of occurrence of koalas as estimated by probability of occurrence (OEH 2015a). Density of occupation by koalas varies substantially, with high fertility landscapes having a higher possibility of high density populations. The most complete, accurate map of koala likelihood of occupation is the 'Koala likelihood of occurrence' map (OEH 2015a). For analysis purposes, occupancy of koalas within ARKS is assumed.	OEH 2015a	Area	Moderate

Step 4: Quantify the risks posed to koala values by the threats

Assignment of risk classes

It is consistent with recommended NSW Government practice to assign relative risk rankings to identified threats. Table 6 presented below is a standard risk assessment matrix, used to relate the likelihood of a threat event occurring to the consequence of the event, to ascribe a level of risk.

The risk parameters were designed to be applied over the timeframe of the SoS Iconic Koala Project, which aims to secure the koala in the wild for the next 100 years. Therefore, the likelihoods of threat events have been scaled to take account of longer-term threats such as the impacts of climate change on habitat suitability.

Table 7 and Table 8 respectively define the likelihood and consequence criteria used to derive the risk classes in Table 6. While current models for climate change and climatic variables do not extend over the 100-year timeframe, both NARCliM (OEH 2016b) and Briscoe et al. (2016) models extend to the period 2060–2079 (approximately 50 years).

Assessing the level of risk to koala values associated with threatening processes is a key step in prioritising appropriate conservation actions outlined in the action toolbox, which seeks to address the full range of social, economic and environmental threats to koala populations.

Table 6 Risk assessment matrix

LIKELIHOOD	LEVEL OF RISK				
ALMOST CERTAIN	MINIMAL	LOW	MODERATE	HIGH	VERY High
LIKELY	MINIMAL	LOW	MODERATE	HIGH	HIGH
POSSIBLE	MINIMAL	MINIMAL	LOW	MODERATE	HIGH
UNLIKELY	MINIMAL	MINIMAL	MINIMAL	LOW	MODERATE
RARE	MINIMAL	MINIMAL	MINIMAL	MINIMAL	LOW
CONSEQUENCE LEVEL	INSIGNIFICANT	MINOR	MODERATE	MAJOR	CATASTROPHIC

Table 7 Likelihood level and definition

Likelihood level	Definition
Almost certain	Expected to occur regularly throughout each year
Likely	Expected to occur multiple times per year
Possible	Not expected to occur annually, but expected within a 5-year period
Unlikely	Not expected to occur within the next 5 years, but expected within a 20-year period
Rare	Not expected to occur within the next 20 years, but expected within a 100-year period

Table 8 Consequence level and definition

Consequence level	Definition
Insignificant	The impact of the threat event, where present, has no discernible effect on koala populations, either locally or at a wider level.
Minor	The impact of the threat event has no discernible effect on koala populations at a wider level. Some localised effects may be present.
Moderate	The impact of the threat event has a moderate effect on wider populations, with a relatively short (5–10 year) recovery period.
Major	The impact of the threat event has a major effect on wider populations, with a relatively long (10–20 year) recovery period. Localised extinctions are possible.
Catastrophic	The impact of the threat event has a catastrophic effect on wider populations, with an intergenerational (20+ years) recovery period. Wider extinctions are possible.

The threat versus consequence matrix

It is an accepted fact that not all threatening processes have the same consequence when considered across the range of values important to koalas and koala habitat. For instance, vehicle collisions have a high level of consequence to occupancy (koala individuals within a population), but no measurable consequence on forest maturity. Conversely, habitat loss and fragmentation have a major effect on connectivity and forest maturity, but a much lesser *immediate* effect on occupancy, though the longer-term effects of habitat loss will eventually cause a reduction in koala numbers through associated threatening processes.

Table 9 below designates the level of consequence for a threat event to each of the identified koala values. Using these assigned consequence categories and mapped likelihood categories (from the threat mapping), a risk range for each threat/value combination has been assigned (refer Appendix B). For instance, the risk range to forest maturity from vehicle collision is insignificant, regardless of the likelihood, whereas the risk to occupancy from vehicle collision ranges from minimal (rare likelihood) to high (almost certain).

Appendix B contains the final risk categories that will be used to apply numerical modifiers to mapped koala values to determine their resilience to current and future threats. The method for determining how resilience is calculated is outlined in Step 5.

Table 9 Consequence mapping for threat groups and koala values

Threat group	Consequence score				
	Forest maturity	Refugia	Connectivity & integrity	Habitat suitability	Occupancy
Habitat loss, fragmentation and degradation	MAJOR	MAJOR	MAJOR	MAJOR	MODERATE
Collisions with motor vehicles	INSIGNIFICANT	INSIGNIFICANT	MAJOR	INSIGNIFICANT	MAJOR
Predation by wild or domestic dogs	INSIGNIFICANT	INSIGNIFICANT	MAJOR	INSIGNIFICANT	MODERATE
Wildfire and intense prescribed burns	MAJOR	MINOR	MINOR	MINOR	MAJOR
Drought	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	MAJOR
Heatwave	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	MAJOR
Disease	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	INSIGNIFICANT	MODERATE
Reduction in suitability of habitat from the effects of climate change	INSIGNIFICANT	MAJOR	INSIGNIFICANT	CATASTROPHIC	CATASTROPHIC

Step 5: Quantify the likely resilience of koalas to the identified risks

Rationale

An understanding of the relative risk and resilience of areas of significance for koalas is useful in helping to guide how actions are prioritised across these areas in New South Wales. The resilience of ARKS, as defined in this report, is a function of the values (habitat and occupancy) and the level of risk they are exposed to by threatening processes.

Resilience has been quantified spatially (determined for each ARKS as measured from functional habitat) by analysing the risk mapping and value mapping within a matrix of weighted modifiers to give an overall estimate of likely persistence. In addition to resilience, ARKS security has been assessed as a function of predicted sensitivity to loss and the land tenure status of koalas. These measures are designed to be a surrogate for a viability assessment in lieu of accurate koala population data.

Resolution, assumptions and sampling bias

To undertake a spatial analysis of this type, a number of assumptions regarding the use of data have been made. Key decisions regarding the spatial scale, the type of datasets to include and the way each is incorporated, have been informed by the Spatial Dataset Audit (Rennison 2017a) and by preceding studies concerning risk analysis processes. The details of how each dataset has been used in the analysis and its limitations, have been included in the profiles of values and threats (Appendix D).

Spatial scale

Resilience values have been calculated on a grid square basis at a nominal resolution of 500 metres. This resolution has been determined as the minimum scale which can account for the spatial variability of the component threat and value datasets which make up the analysis. An important consideration for this decision was home range movements of koalas across their range. The analysis grid resolution (500 m) has been chosen to represent a median coastal koala female home range, estimated to be 25 hectares.

Risk surfaces from linear and fine-scale threats (such as roads) are only able to be represented at fine scale; however, climatic risk surfaces such as heatwave are only available at a continental scale.

Temporal scale

The temporal scale of the resilience analysis has been set nominally at 50 years. This scaling has been applied through the likelihood class rankings and constrained by available data, notably the climate change modelling (Briscoe et al. 2016) and the NARCliM modelling of climatic variables (OEH 2016b).

Selection of threat and value criteria

A number of sources of information were consulted in the selection of criteria for analysis of threats and values. Major studies consulted in the process of criteria selection include:

1. Koala Threat Mapping for Conservation Management, Interim Report to the NSW Office of Environment and Heritage, 16 June 2016 (Smith, Lunney & Moon 2016)

2. Recovery plan for the koala (*Phascolarctos cinereus*), November 2008, Department of Environment and Climate Change (DECC 2008)
3. Species Profile and Threats Database (SPRAT) profiles (DEE 2017)
4. Threatened Species Scientific Committee determination (DSEWPAC 2012).

Other studies used in the formulation of threat and value mapping are referred to in each profile outlined in Appendix D.

Sampling bias

It is well recognised that only a small proportion of mapped or modelled koala habitat has been subject to adequate survey. Of the approximate 22,000 records of koalas in New South Wales since 1990, the majority are derived from non-stratified or non-systematic survey, with the largest single contributor being default ATLAS sightings at over 7000 records. As a result, there is a low degree of confidence in koala likelihood of occurrence for large parts of New South Wales (OEH 2015a). With this clear bias of survey effort in mind, it is important that resilience measures are viewed in the context of the confidence ranking for each likelihood of occurrence grid (OEH 2015a). Each resilience profile map displays areas of low confidence (or no data) to highlight areas where there is a high degree of uncertainty around koala occupancy information.

Values scoring for integrity mapping

Values scoring for ARKS has been undertaken against five criteria outlined in Table D.1 and detailed in Appendix D, *Values assessment profiles.* Each value criterion contributes equally to the final values integrity score for an area, as each of the criteria are considered of high importance to koalas.

It is accepted that the mapping presented in this framework is regional in nature and is suitable only for strategic planning purposes. Local planning documents such as Comprehensive Koala Plans of Management, where they exist, are the most appropriate resource for assessing koala values at the property scale.

The values integrity mapping has two proposed roles in the framework for koala prioritisation:

1. Current value of areas for koala conservation

The values integrity score provides an overall relative measure of an area's capacity for contributing to koala conservation through security of habitat and koala populations. The areas represented as high and very high value should be considered important for retention as koala habitat.

2. Contribution to the calculation of resilience for areas of regional significance

Values integrity mapping provides an important step in determining the resilience of ARKS. The integrity mapping provides a baseline measurement of koala values against which threatening processes are analysed to determine functionality of habitat (see Figure 6 below).

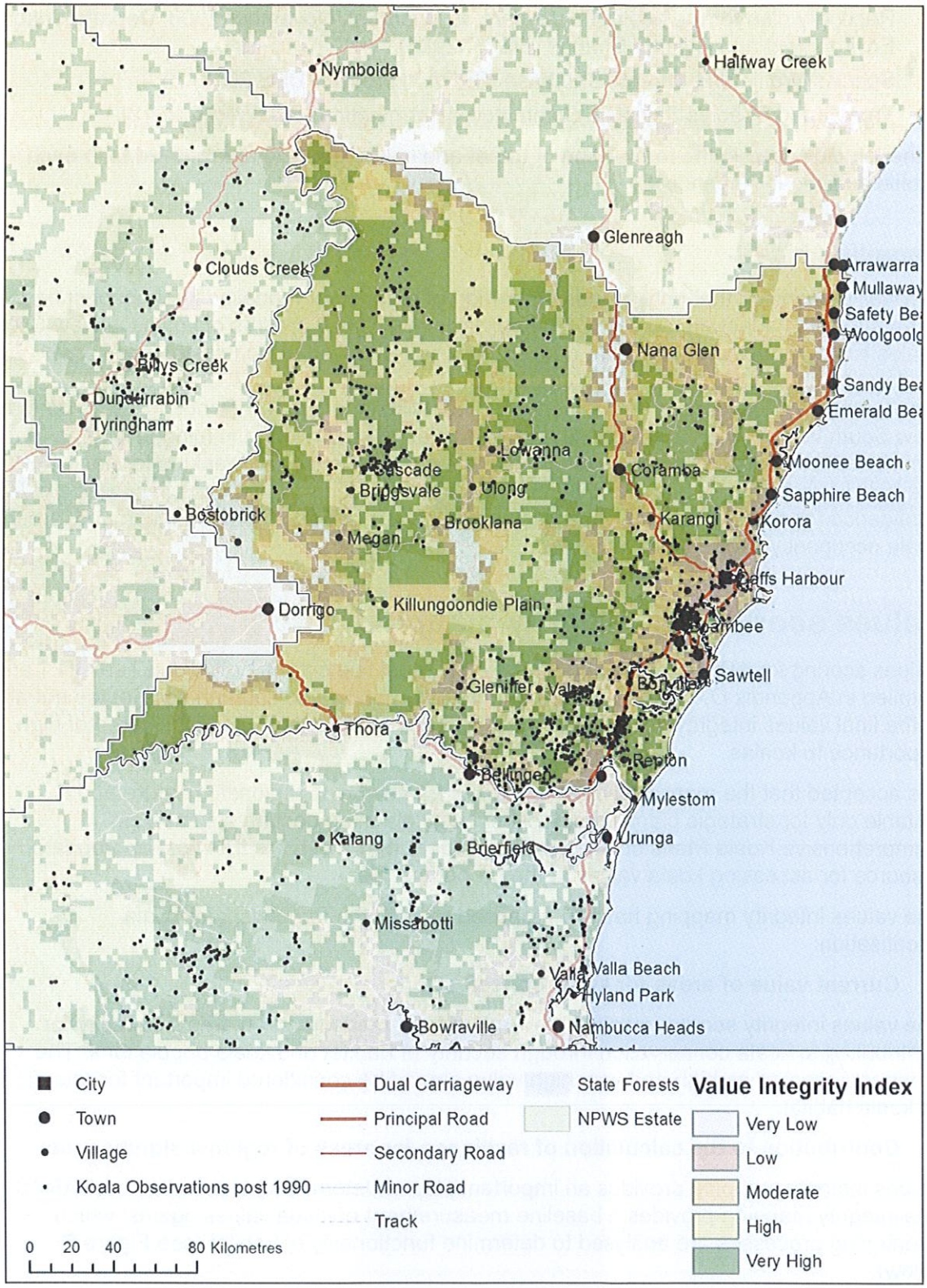


Figure 6 Values integrity mapping example, Coffs Harbour – North Bellingen

Resilience class and security for Areas of Regional Koala Significance

The resilience class is an area-scale measure of the future predicted ability of koala areas to withstand loss of habitat and occupancy from threatening processes. The resilience and security measures are modelled using the functional habitat classification in a three-step process:

1. calculation of the functional habitat score for each 500 m grid cell (site scale), then
2. allocation of a resilience class to each ARKS
3. allocation of a security class based on the overall quantity of functional habitat within the ARKS.

The resilience class is a representation of the likely future persistence of each ARKS based on assumptions of threat level from current information and future modelled climatic predictors (e.g. NARCliM (OEH 2016b); Briscoe et al. 2016).

As accurate koala population information is not widely available across New South Wales, resilience class is not a measure of population viability; that is, a low resilience class does not translate directly to a low viability population, although, in the absence of accurate population data, it is intended to serve as a broad surrogate.

Calculating site-scale functional habitat in an ARKS

Functional habitat is defined within the framework as being land which is expected to be able to support koala populations into the future, given current assumptions of threatening processes. For the purposes of calculating resilience at an area scale, only two classes of functionality are recognised. For the purposes of visualisation within profile areas, all four analysis classes are represented on the resilience maps.

The functional habitat for an area of land (calculated on a 500 m grid square basis) is estimated through the application of a series of spatial modifiers which are the expression of the risk level for that area. Appendix C illustrates how each risk layer impacts differentially on each of the mapped value layers. The degree of impact of each threat layer on each value has been determined through a series of assumptions recorded in Table 9 (threat consequence) and likelihood mapping in Appendix D. Calculations for each grid square are made on the spatial correspondence of the mapped risks with the mapped values.

Risks for threatening processes are cumulative and therefore modifiers are multiplied for each risk that is impacting on a value. Standard modifier values for each risk class have been developed and are presented in Table 10. The modifiers represent the likely reduction factor, due to each threat risk, of mapped koala values over the scenario period (50 years).

Table 10 Risk level and spatial modifier scores

Risk level	Spatial modifier
Minimal	1.0
Low	0.85
Moderate	0.65
High	0.5
Very high	0.2

Once the risk modifiers have been applied and resilience scores calculated, each grid cell is then classified as either *Moderate – High functionality* or Low – Very low *functionality*, as described in Table 11 below. The purpose of this classification is to distinguish between lands which have the capacity to support koala populations in the long term, and those where, with current threatening processes, koalas are not expected to persist.

The process for calculation of resilience is represented below. The risk modifiers (R_x) are applied to each value (V_x), and these are then summed and rescaled (0–5). Weightings were applied to each of the value scores, with higher weightings given to koala occupancy and habitat suitability (1.5), and lower to forest maturity and landscape integrity (0.5). These weightings were applied in consideration of the relative importance of each value criterion to the persistence of koalas. The resilience calculation was undertaken for every 500 metre grid cell in the analysis area (eastern New South Wales).

$$\begin{aligned}
\text{RESILIENCE CELL}_x = {} & V_{FM}(R_{HL}{*}R_F{*}R_{VS}{*}R_{DA}{*}R_{Di}{*}R_{HS}{*}R_{CC})W_{FM} && \{\text{forest maturity value with risk modifiers}\} \\
& + V_{LI}(R_{HL}{*}R_F{*}R_{VS}{*}R_{DA}{*}R_{Di}{*}R_{HS}{*}R_{CC})W_{LI} && \{\text{landscape integ. value with risk modifiers}\} \\
& + V_{HS}(R_{HL}{*}R_F{*}R_{VS}{*}R_{DA}{*}R_{Di}{*}R_{HS}{*}R_{CC})W_{HS} && \{\text{habitat suitability value with risk modifiers}\} \\
& + V_{RR}(R_{HL}{*}R_F{*}R_{VS}{*}R_{DA}{*}R_{Di}{*}R_{HS}{*}R_{CC})W_{RR} && \{\text{riparian refugia value with risk modifiers}\} \\
& + V_{KO}(R_{HL}{*}R_F{*}R_{VS}{*}R_{DA}{*}R_{Di}{*}R_{HS}{*}R_{CC})W_{KO} && \{\text{koala occup. value with risk modifiers}\}
\end{aligned}$$

where:

V_{FM} = value score for forest maturity

V_{LI} = value score for landscape integrity

V_{HS} = value score for habitat suitability

V_{RR} = value score for riparian refugia

V_{KO} = value score for koala occupancy

R_{HL} = risk modifier for habitat loss & fragmentation

R_F = risk modifier for fire

R_{VS} = risk modifier for vehicle strike

R_{DA} = risk modifier for dog attack

R_{Di} = risk modifier for disease

R_{HS} = risk modifier for heat stress

R_{CC} = risk modifier for climate change

W_{FM} = weighting for forest maturity

W_{LI} = weighting for landscape integrity

W_{HS} = weighting for habitat suitability

W_{RR} = weighting for riparian refugia

W_{KO} = weighting for koala occupancy

Table 11 Functional habitat categories

Functionality level	Functional habitat score	Resilience level	Map code	Characteristics
Moderate – High functionality habitat	2.0 – 5.0	Moderate – High	HIGH (3.5 – 5.0)	Koala habitat that has a moderate to high level of integrity and future expected resilience based on current and projected risk from mapped threats.
			MODERATE (2.0 – 3.5)	
Low – Very low functionality habitat	0.0 – 2.0	Low	LOW (1.0 – 2.0)	Koala habitat that has a low level of integrity and future expected resilience based on current and projected risk from mapped threats.
			VERY Low (0.0 – 1.0)	

Allocating a security class for each ARKS

ARKS were ranked according to the security afforded by both conservation management and the overall extent of functional habitat within the ARKS.

Conservation management analysis

Extent of conservation management has been measured in terms of the relative proportion of koala observation records on both formal and informal reserve. Each ARKS was classified as one of three reservation categories:

High reservation	**>50% of records within conservation management**
Moderate reservation	**30–50% of records within conservation management**
Low reservation	**<30% of records within conservation management**

The categories of conservation management lands included in the reservation assessment analysis are:

- national park estate
- conservation agreements (VCAs)
- wildlife refuges
- Indigenous protected areas
- registered property agreements (in perpetuity)
- Nature Conservation Trust – conservation covenants
- biobanking agreements
- other private conservation agreements include Bush Heritage Australia and Australian Wildlife Conservancy
- property vegetation plan (PVP) incentive lands
- PVP offset lands
- PVP conservation lands
- flora reserves
- southern mallee reserves.

Sensitivity to loss analysis

The sensitivity to loss within each ARKS has been estimated by assessing the availability of functional habitat to support a minimum population of 50 breeding females (ELA 2014). For this analysis, a variable assumption of home range was adopted, with females in southern ARKS assumed to have a home range of 175 hectares. By comparison, north coast and hinterland ARKS were assumed to have a home range of 20 hectares. Although variable, western and Sydney Basin ARKS were assumed to have a home range of 30 hectares and tablelands ARKS were given a nominal home range of 25 hectares. These figures were collated through internal OEH advice, expert advice (pers. comm. Stephen Phillips 2017) and available literature (Paull & Hughes 2016).

ARKS determined to have a high sensitivity to loss are typically fragmented areas with a reduced capacity to support koala populations. These areas are often subject to elevated threat levels depending on the spatial and site level context.

ARKS identified as having a low sensitivity to loss are characterised as having greater overall quantity of functional habitat and connectivity, which puts them at a low risk of population collapse. High sensitivity to loss ARKS are commonly smaller in size; however, this trend is not uniform and many larger western ARKS have a high sensitivity to loss because of compounding threats.

Table 12 summarises the criteria for each sensitivity to loss class.

Table 12 Areas of Regional Koala Significance – sensitivity to loss classes

Sensitivity class	Sensitivity criteria
High sensitivity to loss	Less than the area of (moderate or high) functional habitat modelled to support a population of 50 females
Moderate sensitivity to loss	More than the area of (moderate and high) functional habitat modelled to support a population of 50 females
Low sensitivity to loss	More than twice the area of (moderate and high) functional habitat modelled to support a population of 50 females

Calculating the security of an ARKS

Having calculated the sensitivity to loss and reservation level of each ARKS, the security is allocated from the matrix below (Table 13), a relative measure from high to low. Secure areas are deemed to be areas of larger size and functionality, where a higher proportion of koalas are recorded within lands managed for conservation. Low security areas, conversely, are those which are smaller, have a lower overall functionality, and in which a higher proportion of koalas are recorded outside lands managed for conservation.

Table 13 Matrix to determine security classes of Areas of Regional Koala Significance

	Reservation level (based on koala records of occurrence)		
Sensitivity to loss	**High** (50% records in reserve)	**Moderate** (30–50% records in reserve)	**Low** (<30% records in reserve)
Low	High	High	Moderate
Moderate	High	Moderate	Low
High	Moderate	Low	Low

Allocating a resilience class for each ARKS

For each ARKS, a resilience class has been allocated using a simple classification of the predicted functionality of habitat within the defined area. There are three resilience classes, which are defined in Table 14.

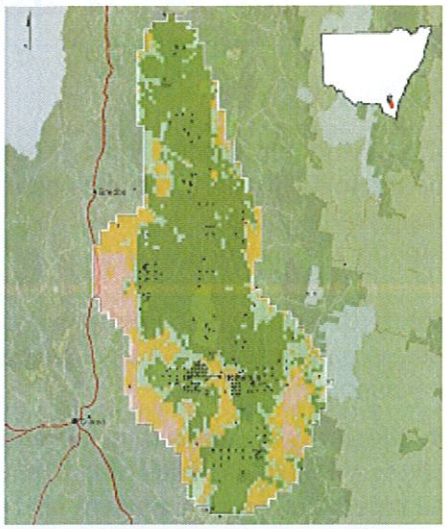
Table 14 Areas of Regional Koala Significance resilience classes

Resilience class	Resilience criteria	Characteristics
High resilience population	70% or higher (Moderate – High) functional habitat	Consolidated population with stable and secure land use, either managed for conservation or with dominantly passive use. Other threats have low to moderate influence. Active mitigation of threats not typically required. May be suitable for conservation management.
Moderate resilience population	30–70% (Moderate – High) functional habitat	Partially fragmented, but still retaining significant areas of functional habitat. Typically, mixed land use requiring active mitigation in some areas. Priority for acquisition for conservation and BCT investment.
Low resilience population	Less than 30% (Moderate – High) functional habitat	Highly fragmented, retaining only pockets of functional habitat. Occurring in landscapes which have intense land-use practices (generally agriculture in the west and urbanisation on the coast). Priority for site-based threat mitigation and landscape strategies to protect, restore and connect habitat.

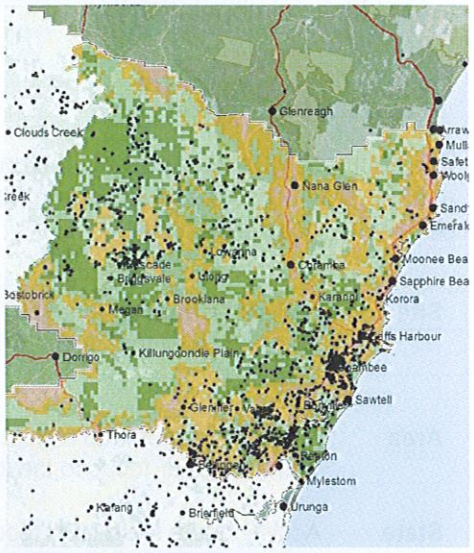
Table 15 below gives three examples of ARKS classified as High, Moderate and Low resilience, together with a brief account of land use and dominant threats. The full profiles for each area are provided in Appendix A.

Table 15 Example Areas of Regional Koala Significance with resilience class allocation

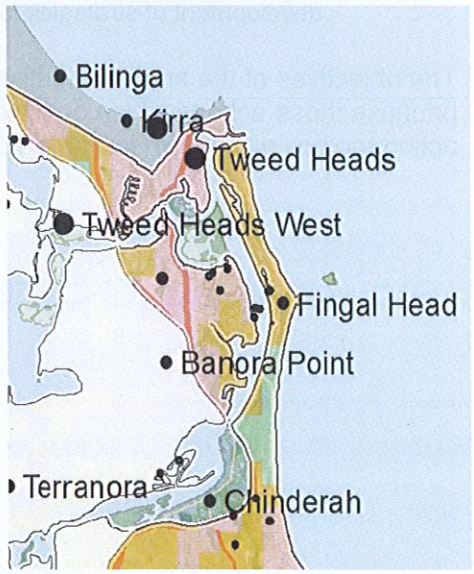
ARKS name: Numeralla	
Resilience class	High
Security	Moderate
Characteristic land use	Passive with some conservation management
Dominant threats	Fire



ARKS name: Coffs Harbour – North Bellingen	
Resilience class	Moderate
Security	Moderate
Characteristic land use	Mixed. Conservation management, forestry, rural and urban.
Dominant threats	Habitat fragmentation, dog attack



ARKS name: Tweed Coast – North	
Resilience class	Low
Security	Low
Characteristic land use	Mixed. Conservation management, forestry, rural and urban.
Dominant threats	Dog attack, habitat fragmentation, vehicle strike



Step 6: Identify the most appropriate strategies within the action toolbox to effectively mitigate threats in each area

Rationale

The Saving our Species Iconic Koala Project identifies a set of actions to address critical threats to the koala, which has been termed the *action toolbox*. The actions have been designed to address the broad range of threats operating on koalas in the NSW landscape, through a variety of approaches including support for community carer groups, scientific research, improved coordination of land management activities, improvement in the standard, coverage and maintenance of core koala datasets, and the support of programs to restore and increase the area of koala habitat in land demonstrated to have koala populations.

To effectively and efficiently mitigate threats to koala areas, actions should reflect the management capabilities of land managers and be assigned as such. Furthermore, land managers can seek to acquire land, enter into partnerships or apply management strategies to protect local populations.

The action toolbox

For each of the prescribed actions in the action toolbox, a scale of operation has been assigned, which indicates the relationship of the activity to the landscape; the three scales being site, area and state.

Site Activity is targeted to a specific property or location, where an on-ground activity is being undertaken. Benefits are directed to that location and are typically able to be measured over time.

Area Activity is targeted to a local community or local government area. Benefits are directed with a broader focus to the local population or community.

State Activity has a state level focus, often to improve understanding of koalas and the development of strategies to better manage resources. Benefits are directed statewide.

The objectives of the spatial prioritisation of SoS koala projects is focused on assisting to prioritise those actions which operate at a *site* or *area* scale. The full set of actions from the action toolbox are shown in Table 16.

Table 16 Saving our Species Iconic Koala Project action toolbox

Threat	Action description	Scale
Loss, modification and fragmentation of habitat	In areas where a koala population is present, undertake restoration works to improve the quality and increase the area of koala habitat. Restoration and augmentation works may include bush regeneration, fencing, weed and pest control, augmentation planting and/or direct seeding in areas of degraded and/or potentially suitable habitat. Appropriate feed and shelter tree species should be used in revegetation works. Restoration works should focus on expanding existing smaller areas of known occupied habitat, including private land, and connecting areas of suitable habitat to create corridors for movement. Resources for long-term monitoring and management of restored areas should be included.	Site
	In areas where a koala population is present, negotiate agreements with landholders, particularly in-perpetuity covenants or stewardship agreements that promote the protection and retention of high quality koala habitat or habitat that contributes significantly to connectivity in the landscape.	Site
	In areas where a koala population is present, undertake koala habitat studies and mapping using standardised methods and terminology to identify key koala populations, and rank and map koala habitat.	Site, area
Vehicle strike	Identify blackspots where koala road mortalities are greatest and target proven mitigation techniques such as fencing and wildlife crossings, in discussion with council and Roads and Maritime Services. Mitigation may also involve the development, testing and deployment of new technologies that can reduce vehicle strike.	Site
	Liaise with Roads and Maritime Services and local councils in the development of new/existing roads to plan koala barrier fencing and crossings as part of road construction projects.	Site
Predation by wild or domestic dogs	Conduct local community awareness campaigns in areas where attacks by domestic dogs on koalas are prevalent to raise awareness of the impacts and the importance of responsible dog ownership, including keeping dogs restrained on leads and in properly fenced enclosures.	Area
Intense prescribed burns or wildfires that scorch or burn the tree canopy	Liaise with relevant authorities or land managers to ensure that identified koala habitat areas are defined as assets for protection in fire planning tools when managing wildfires and prior to any hazard reduction burns. Promote best practice fire management protocols in areas of significant koala populations.	Area
	Liaise with authorities or land managers to ensure that any unavoidable prescribed burns within koala habitat are conducted in a way that minimises impacts on koala habitat and individual koalas, based on best practice guidelines.	Site, area
Koala disease	Improve understanding of the role of chlamydia and other diseases in koala population dynamics and mortality, including baseline genetic information and links between habitat disturbance and disease-related morbidity, by conducting research in collaboration with universities, vets and ecologists.	State

Threat	Action description	Scale
Heat stress through drought and heatwaves	Support carer and vet networks in their response to the management of koala health and welfare during extreme weather conditions.	Area, state
	Research and trial adaptation management actions such as installation of artificial water sources and the establishment of refuge habitat, and promote connectivity through habitat restoration.	Site, area
Human-induced climate change	Use predicted climate change data and modelling techniques to predict the possible impacts on koalas from climate change. This should include how koala habitat is likely to change under different climate change scenarios, such as temperature rise impacts on habitat, drought and wildfires. Use this information to prioritise adaptation actions and investment in habitat and corridor protection and restoration.	Area, state
Inadequate support for fauna rehabilitation	Support koala rehabilitation groups and vets to rehabilitate sick and injured koalas through training, provision of materials, and promotion of statewide protocols including for rehabilitation, genetic profiling, record-keeping and release to the wild.	State
Lack of knowledge (poor understanding of sources of trauma and mortality)	Engage with koala rehabilitation groups and other information sources to better understand the causes of koala trauma and mortality. Collate and map the results.	State
Lack of knowledge (poor understanding of population distribution and trend)	Develop standardised methods and reporting for monitoring change in koala populations and distribution through time and contribute survey data to centralised database. Include genetic information where possible.	State
	Support the collation of koala survey records and monitoring information through a centralised database for statewide reporting and analysis, contributing records to NSW BioNet.	State
Lack of knowledge (poor understanding of animal movements and use of habitat)	Improve understanding of koala movements and use of their habitat in the landscape by conducting targeted research on individuals using GPS collars and mark–recapture techniques.	Area
Getting the community engaged in koala conservation	Use multiple channels to engage the community in koala conservation and recovery actions across the state. This includes communication strategies, citizen science, volunteers, on-ground conservation actions, awareness programs, and landholder engagement.	State

Assigning priority actions using security and resilience

Context

There is a need to provide regional-scale guidance for *Saving Our Species* project managers and other stakeholders in the status and future expected persistence of koala occupied areas in New South Wales.

The following information is best used to guide prioritisation of actions at the regional scale. While the metrics provided in this report give a meaningful representation of expected koala resilience, threats and security, the results cannot be directly interpreted at a site scale. Decision-making at the local and site scale must always be guided primarily by the best available local information, including Koala Plans of Management (where they exist), other relevant local plans, and advice from recognised local experts.

Security versus viability

Identifying populations with a high security can be best achieved if accurate estimates of population size and recorded occurrence information are available. The Koala Spatial Dataset Audit (Rennison 2017a) identified only limited population size information, mainly associated with koala habitat studies for Comprehensive Koala Plans of Management. This information was generally collected at a local scale and cannot easily be translated up to the regional scale. Some regional population estimates are available for the north coast, however these estimates (Scotts 2013) have a very wide margin of error. Koala observation data, while extensive, is still heavily biased towards areas of high population density (around townships) and lands with a requirement for survey (e.g. state forests).

The security classifications have been provided as a broad surrogate of the potential vulnerability of koala populations in an area in lieu of accurate population data at a regional scale. Users should be aware that these classifications are based on current koala record data and expected koala occupancy with assumptions of home range information.

Setting priorities using resilience class and security

ARKS have been classified into three broad categories for the purposes of prioritising actions. The classification (presented in Table 17 below) is based primarily on resilience and security, but also considers the nature of threats which are acting on the ARKS.

The prioritisation of actions should be made in consideration of the scale at which (and by what mechanism) threats to the area can be mitigated. Threats which can be mitigated at the site or area scale are listed in the action toolbox (Table 16 above). Threats which can be mitigated by land-use change are more easily determined at the property scale, but typically include habitat fragmentation and may also include wildfire, dog attack and vehicle strike.

Threats driven by climatic influences such as heat stress and climate change are difficult to mitigate through site and area-scale actions. Mitigation of site and area-scale threats in landscapes with high predicted climatic threats may help to reduce the overall stress on koala populations, therefore improving resilience overall.

Priorities for NPWS acquisition of koala areas are made based on resilience, reservation level and the extent to which the resilience of an area may be improved by the land-use change (into conservation management).

Appendix E provides a quick reference to all ARKS, including the mapped resilience class, security and dominant threats (to be considered for SoS actions). Other useful statistics are also provided, including a records analysis of reservation, IBRA region and Koala Management Region.

Table 17 Setting priorities for SoS actions and land conservation (acquisition and conservation agreement)

Resilience class	Security	Relevant threats	Priority for action
Low	Low	Threats which can be mitigated at the site or area scale	**Low–moderate for site scale actions** (e.g. mitigation of dog and vehicle mortality) **Moderate for area scale actions** (e.g. refugia and connectivity projects)
Moderate or high	Moderate or high	Threats which can be mitigated at the site or area scale	**High for site and area scale actions** (e.g. SoS actions for vehicle strike, dog attack, habitat restoration and connectivity).
Moderate or high	Low	Threats which can be mitigated by land-use change	**High for acquisition priority and other conservation strategies** (e.g. NPWS acquisition and BCT programs)

Interpreting the ARKS profiles

Introduction and overview

An ARKS profile has been assembled for each of the 48 Areas of Regional Koala Significance. The profile contains a map of the area complete with resilience class, security class, functional habitat classes, threat likelihood maps and a concise set of critical statistics.

Of the 48 ARKS recognised by this study in New South Wales, 13 have been ranked as high resilience, 22 as moderate resilience and 13 as low resilience. Figure 7 below displays the resilience rank for these areas across eastern New South Wales, while Figure 8 displays their security rank. Appendix C provides an alphabetical list of areas with their corresponding resilience rank while Appendix D lists them with their security rank.

There is a clear pattern of declining resilience in western New South Wales and parts of the north coast. This decline reflects the intensity of mapped threatening processes acting on koalas. For areas in western New South Wales, threats influenced by climatic factors (such as heat stress, fire and climate change) are strongest, while in coastal areas, the urban and development-related threats such as habitat loss, vehicle strike and dog attack have the most influence.

When assessed at a bioregional scale, the resilience trends are more apparent, with eight of the 13 low resilience areas in western bioregions and four of the remaining five in South Eastern Queensland Bioregion. High resilience areas are more evenly distributed, with the south east well represented (three areas) and most of the remainder in the NSW North Coast and Sydney Basin bioregions.

Table 18 lists the number of high, moderate and low resilience koala areas by bioregion.

Table 18 Resilience class of Areas of Regional Koala Significance by bioregion

Bioregion	High resilience	Moderate resilience	Low resilience	Total
Brigalow Belt South			4	**4**
Nandewar		1	1	**2**
New England Tablelands	1	1	1	**3**
NSW North Coast	6	12		**18**
NSW South Western Slopes			1	**1**
Riverina			1	**1**
South East Corner	2			**2**
South East Highlands	1		1	**2**
South Eastern Queensland		6	4	**10**
Sydney Basin	3	2		**5**
Total	**13**	**22**	**13**	**48**

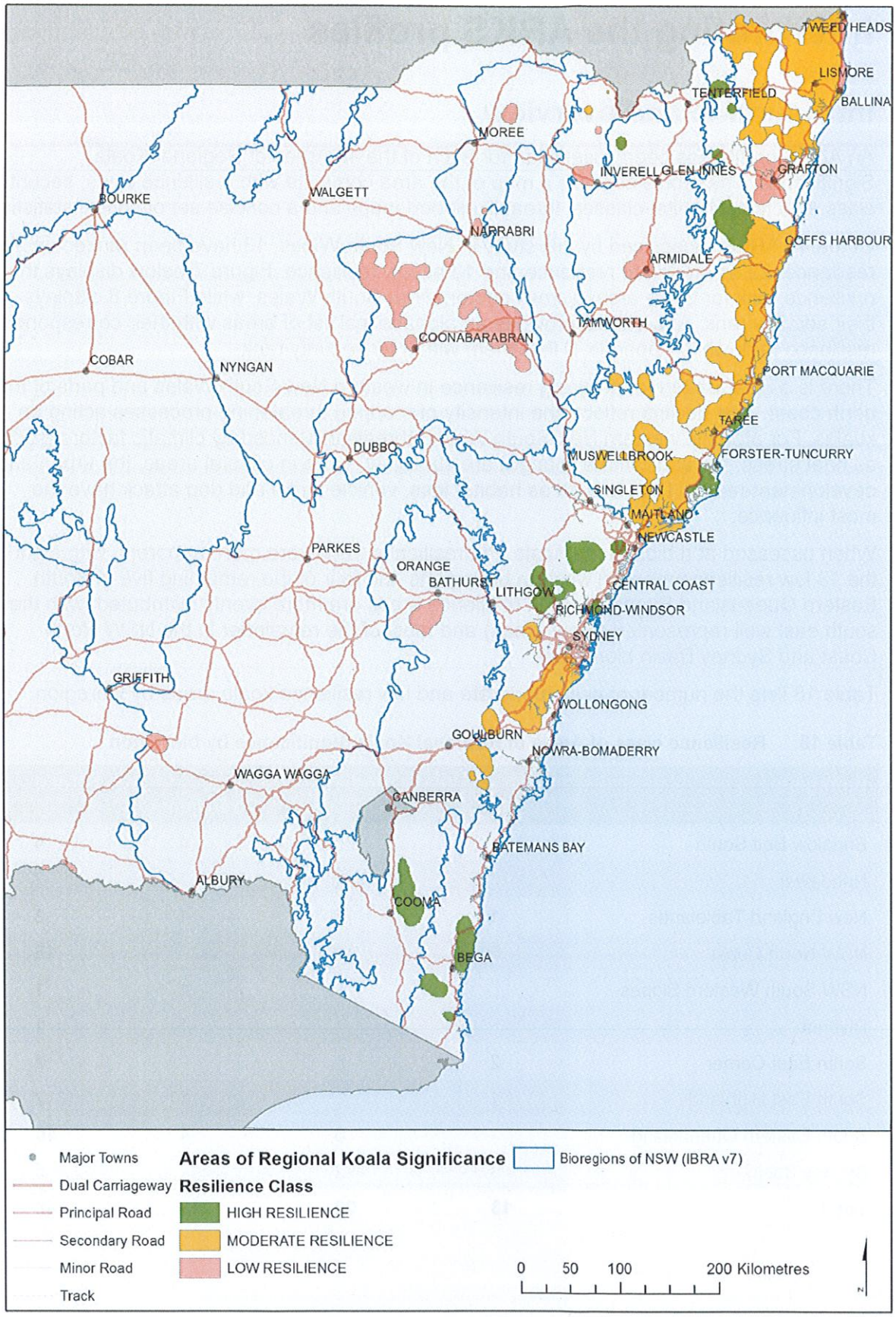


Figure 7 Resilience of Areas of Regional Koala Significance for New South Wales

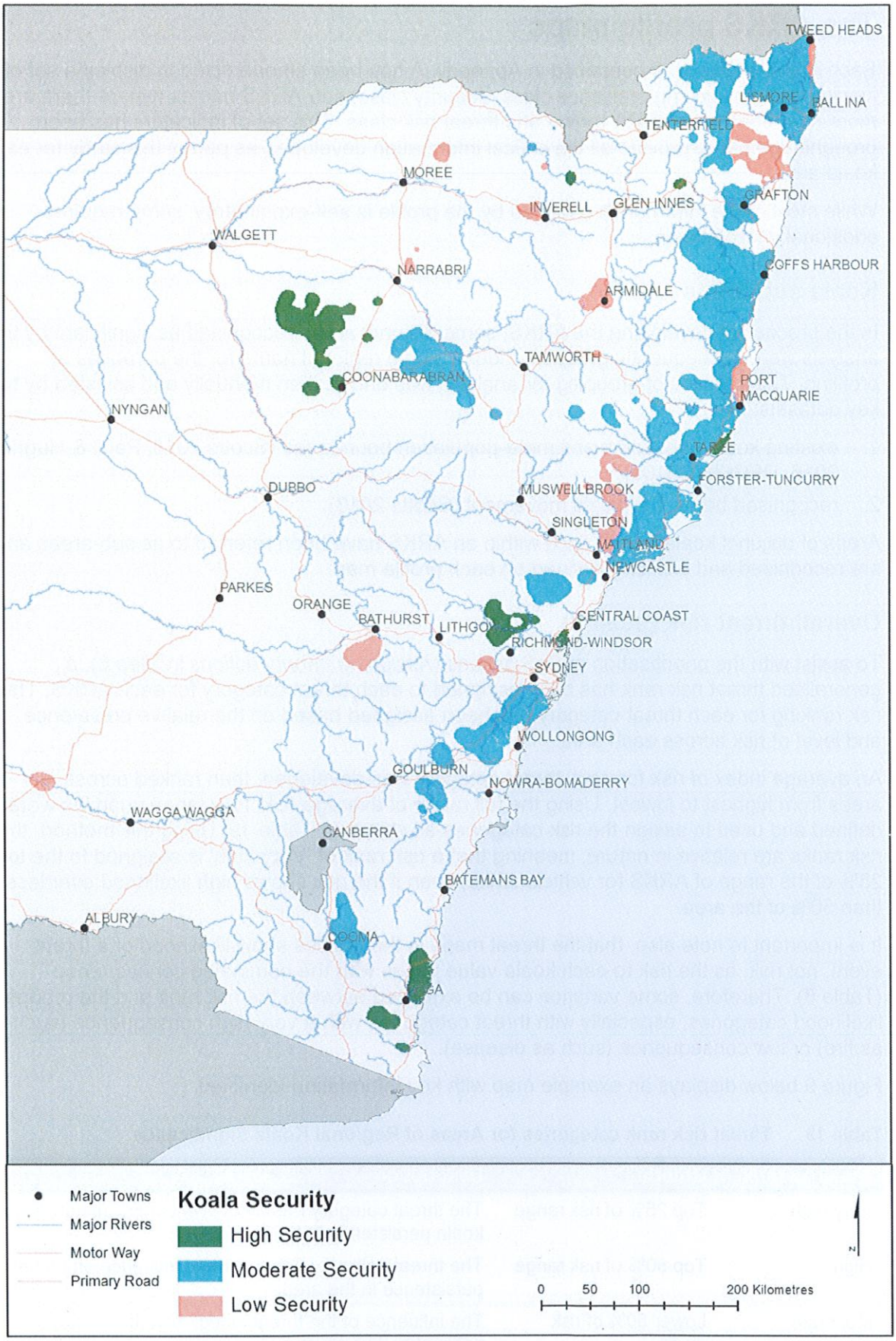


Figure 8 Security of Areas of Regional Koala Significance for New South Wales

The ARKS profile maps

Each ARKS profile map contained in Appendix A has been standardised to display a set of key indicators including resilience class, security class, sub-ARKS names (where there are more than one), area, IBRA region and threat risk class. This set of indicators has been brought together to provide all the critical information developed as part of this study for each koala area.

While most of the information provided by the profile is self-explanatory, some requires additional interpretation.

Koala sub-areas

In the process of developing the ARKS, some disjunct areas recognised as significant by the analysis were subsequently grouped under a single regional name for the purposes of profiling. This process of grouping for analysis was undertaken manually and assisted by two key datasets:

1. existing koala population and meta-population boundaries (Scotts 2013, Paull & Hughes 2016, DECCW 2010a)
2. recognised barriers to koala movement (Scotts 2013).

Areas of disjunct koala significance within an ARKS have been referred to as sub-areas and are recognised and explicitly defined on each profile map.

Overall threat risk (scaled)

To assist with the prioritisation of SoS actions (*Assigning priority actions* in Step 6), a generalised threat risk rank has been assigned to each threat category for each ARKS. The risk ranking for each threat category has been assigned based on the relative prevalence and level of risk across each area.

An average index of risk for each threat category was developed, then ranked across all areas from highest to lowest. Using the full range of average risk, four range quartiles were defined and used to assign the risk categories as shown in Table 19. Using this method, the risk ranks are relative in nature, meaning that a risk rank of 'Very high' is assigned to the top 25% of the range of ARKS for vehicle strike, even if the risk shows high likelihood over less than 50% of the area.

It is important to note also, that the threat maps in the profiles show likelihood of a threat event, not risk, as the risk to each koala value varies with the nominated consequence (Table 8). Therefore, some variance can be expected between the risk rank and the mapped likelihood categories, especially with threat categories with a very high consequence (such as fire) or low consequence (such as disease).

Figure 9 below displays an example map with key information identified.

Table 19 Threat risk rank categories for Areas of Regional Koala Significance

Area risk rank	Criteria	Description
Very high	Top 25% of risk range	The threat category has an overwhelming influence on koala persistence in the area.
High	Top 50% of risk range	The threat category has a marked influence on koala persistence in the area.
Moderate	Lower 50% of risk range	The influence of the threat category in the area is noticeable, but not prevalent in the area.
Low	Lower 25% of risk range	The threat category is absent, or insignificant in the area.

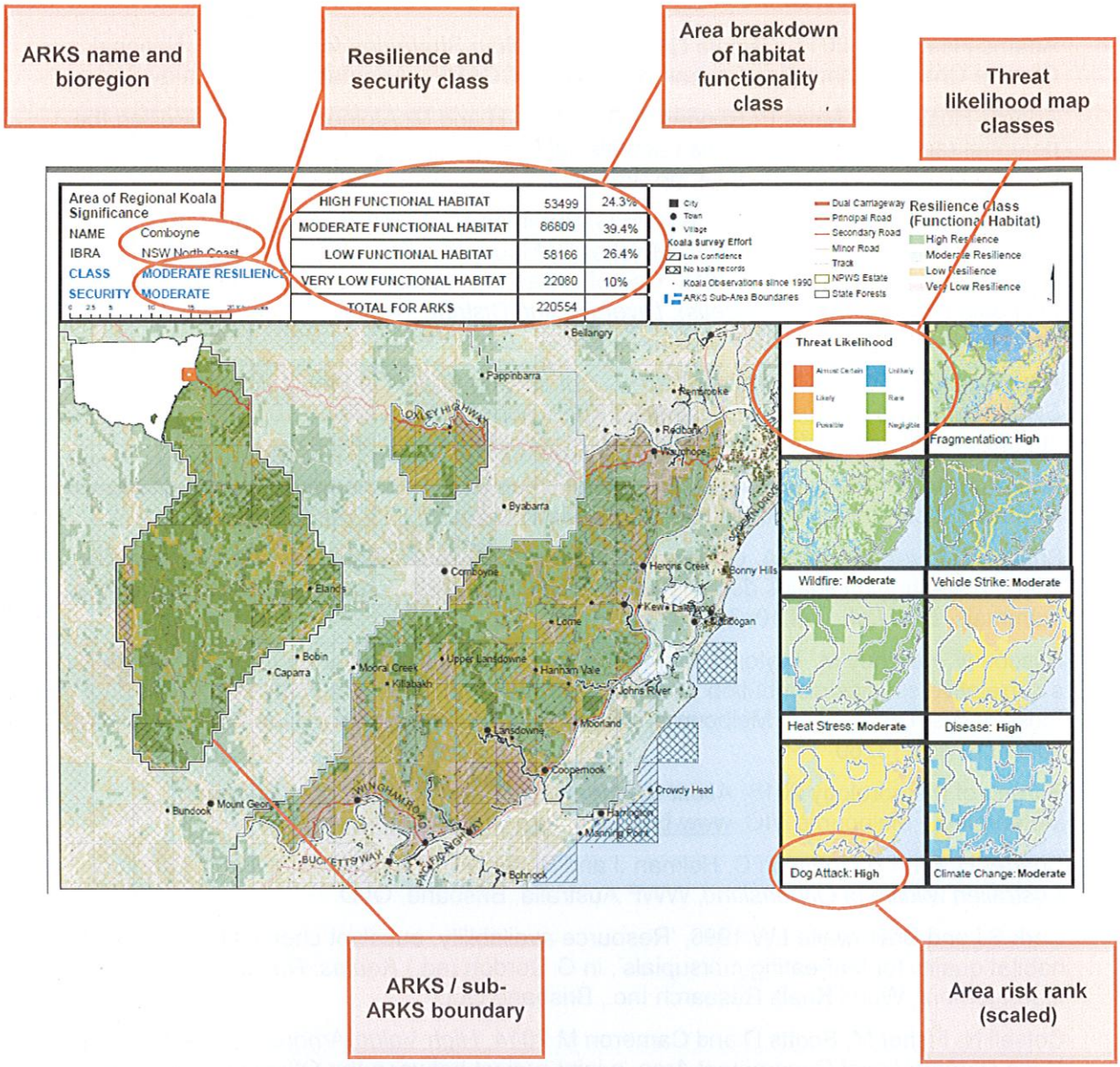


Figure 9 Resilience profile example for interpretation

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Appendices

The following appendices to the document have been supplied as separate files so they can be selectively downloaded.

Appendix A: Areas of Regional Koala Significance – profiles

A detailed profile is provided for each of the 48 Area of Regional Koala Significance (ARKS), including resilience class, security class, sub-ARKS name, area, IBRA region and threat risk class.

Appendix B: Threat versus values – matrix of risk scores

Appendix B contains a risk score matrix for each threat against koala values. It is used to apply numerical modifiers to mapped koala values to determine their resilience to current and future threats.

Appendix C: Areas of Regional Koala Significance – resilience categories

Of the 48 areas of regional koala significance recognised by this study in New South Wales, 13 have been ranked as high resilience, 22 as moderate resilience and 13 as low resilience. The table in this appendix displays the resilience rank for each area (in alphabetical order). The resilience class is a function of the values (habitat and occupancy) and the level of risk they are exposed to by threatening processes (refer to glossary for more information).

Appendix D: Areas of Regional Koala Significance – security categories

Of the 48 areas of regional koala significance recognised by this study in New South Wales, eight have been ranked with high security, 28 with moderate security and 12 with low security. The table in this appendix displays the security rank for each area (in alphabetical order). ARKS security has been assessed as a function of predicted sensitivity to loss and the land tenure status of koalas (refer to glossary for more information).

Appendix E: Spatial analysis of population threats and values

This appendix presents the method and results for the analysis of koala values and threats. For each of the values and threats, a concise profile has been compiled, including the rationale for analysis, the analysis method and the resultant map and map categories.

Glossary

Area of Regional Koala Significance (ARKS)

ARKS are defined as regional scale areas of currently known, moderate to high density of koala occupancy. Spatial ARKS boundaries are based on kernel density analysis of recent koala records (1990–2016). ARKS have been developed for regional scale planning and are regarded as Regional Koala Populations.

Each ARKS map profile contained in Appendix A has been standardised to display a set of key indicators including resilience class, security class, sub-ARKS names (where there are more than one), area, IBRA region and threat risk class. This set of indicators has been brought together for each ARKS to provide all the critical koala information needed for regional koala management.

Values integrity class

The values integrity score provides an overall relative measure of an area's capacity for contributing to koala conservation through habitat values and koala occupancy.

The values integrity mapping is designed as a representation of the overall value of land for koalas, independent of any threatening processes which may be active, or have potential to be active.

Values integrity mapping provides an important step in determining resilience of ARKS. The integrity mapping provides a baseline measurement of koala values against which threatening processes are analysed to determine the functionality of habitat.

Threat likelihood class

Threat likelihood is the potential for koala values to be impacted upon across an ARKS and therefore, the likelihood of diminishing habitat integrity and koala viability.

The threat groups identified by this study and others, including the Chief Scientist & Engineer's report (NSW Chief Scientist & Engineer 2016), have been used as a basis for the identification of threats and the development of strategies to spatially define and quantify their influence on koala occupancy and habitat values. Nine distinct threat groupings have been identified for the purposes of this study to provide a framework for the spatial assessment of these threats across population areas in New South Wales.

Threat groups and definitions, the scale of the process at which the threat operates and the range of koala values impacted directly have been assessed using a matrix to determine the risk and consequence of threats impacting. The scale of determination of threat processes is integral to both strategies for mapping risk and interpreting that risk in a management framework.

It is important to note that the threat maps in the profile show likelihood of a threat event, not risk, as the risk to each koala value varies with the nominated consequence.

Functional habitat class

Functional habitat is defined as land that is expected to be able to support koala populations into the future, given current assumptions of threatening processes.

For the purposes of calculating resilience at an area scale, only two classes of functionality are recognised. For the purposes of visualisation within profile areas, all four analysis classes are represented on the ARKS profile maps.

Resilience class

The resilience class is a function of the values (habitat and occupancy) and the level of risk they are exposed to by threatening processes.

Resilience is an overall estimate of the likelihood of koalas persisting across a region (averaged for the ARKS) given current and future values and threats.

Resilience, together with security class, are designed to be a surrogate for a viability assessment in lieu of accurate koala population data. As accurate koala population information is not widely available across New South Wales, resilience class is not a measure of population viability; that is, a low resilience class cannot translate directly to mean a 'low viability' population.

The resilience class is an area scale measure of the future predicted ability of koala areas to withstand loss of habitat and occupancy from threatening processes.

Security class

Security class is a function of the koala population's sensitivity to loss and the protection afforded to koalas in an area or region based on tenure (koalas in and outside of lands managed for conservation). Sensitivity to loss has been calculated based on the available functional habitat to support a minimum of 50 breeding females.

Secure areas are deemed to be areas of larger size and landscape functionality, where a higher proportion of koalas are recorded within lands managed for conservation. Low security areas, conversely, are those which are smaller, have a lower overall functionality, and in which a higher proportion of koalas are recorded outside lands managed for conservation.