Koala Habitat Mapping pilot

NSW State Forests

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Acronym list

3Ai	3D ADS40 image interpretation
DBH	diameter at breast height (measure 1.3m off the ground)
DPI	Department of Primary Industries
KFT	koala feed tree
LKFT	local koala feed tree
OEH	Office of Environment and Heritage (NSW)
PCT	plant community type
POC	probability of occurrence
RN17	research note 17 forest type mapping
SAT	spot assessment technique

Executive summary

The Koala Habitat Mapping Project was initiated by the NSW Environment Protection Authority (EPA) to pilot alternative approaches to the identification and management of important koala habitat in native forestry areas in northern NSW.

This project aimed to:

- develop a pilot methodology to identify, classify and map koala habitat on state forest
- trial a number of different koala habitat mapping methods within four pilot areas of state forest under different regional environmental conditions
- produce management scale koala habitat mapping (1:5000) for these four pilot areas
- determine the adequacy of the methods in accurately and efficiently identifying koala habitat for the purposes of managing the impact of native forestry operations.

The following mapping methods were the basis for this comparison and determination:

- plant community type (PCT) mapping
- predictive koala habitat modelling (probability of occurrence)[1]
- forest type mapping, Research Note 17, (RN17) that has been reassigned by the Department of Primary Industries (DPI) to develop likely koala habitat class.

Survey and mapping was conducted over 6000 hectares in Royal Camp, Maria River, Clouds Creek and Carwong state forests, between March and June 2015.

The survey effort included koala activity (Spot Assessment Technique), plant community type and koala habitat assessment. A comparative analysis of data was undertaken, and was used to produce a series of map-based products to show koala habitat class, koala 'probability of occurrence', generation persistence and habitat use.

A panel of koala experts (consisting of Dr Steve Phillips, Dr Andrew Smith and Dr Rod Kavanagh) was established to guide considerations and inclusions in the method and analysis of koala habitat classification and mapping.

While resident populations of koala were found in all pilot areas, habitat utilisation was variable across the landscape. Areas of higher activity positively correlated with greater abundance and diversity of local koala feed trees, trees and forest structure of a more mature size class, and areas of least disturbance. Across the landscape, the majority of koala numbers reside in habitat with greater than 15% local koala feed trees in the canopy.

The project results indicate that koala habitat maps produced via the tested methods, can only be reliably used to differentiate between suitable habitat and unsuitable habitat. The variability within vegetation types means it is difficult to accurately map koala habitat classes at a management scale of 1:5000 metres (discussed in Sections 7 and 8). The project findings also indicate that koalas occupy habitat to varying degrees for reasons other than floristic composition.

This project was funded by a Waste and Environment Levy Envelope (WELE) grant, administered through the NSW Environmental Trust. EPA staff and contracted experts carried out survey, mapping, analysis and reporting. Validation of koala class and koala occupancy was independently undertaken by consultants.

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[1] [1]The development of the Koala Model was undertaken by an OEH officer in Coffs Harbour employed on a separate project. While not officially sanctioned, the Koala project team took an opportunity to utilise a local resource who was highly experienced in the use of spatial modelling techniques. OEH may further develop the approach at a future time.

1. Background

This project was initiated by the NSW Environment Protection Authority (EPA) to pilot and evaluate a range of different approaches to the identification and management of koala habitat in native forests in northern NSW.

The project was funded by a Waste and Environment Levy Envelope (WELE) grant administered by the NSW Environmental Trust, as part of a broader three-year $373,000 koala habitat mapping program for both public and private native forestry areas.

The outcomes of this project, and the broader koala habitat mapping program, will be used to inform the development of improved approaches to the identification and management of koalas and their habitat in managed native forests across NSW. This includes the remake of the Coastal Integrated Forestry Operations Approval and Private Native Forestry Code of Practice.

1.1 Koala conservation status

Habitat loss is the dominant threatening process for koala (McAlpine et al. 2015). The koala is now recognised as a threatened species across two thirds of its range and listed as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*. The koala has suffered greater than 50% decline since European settlement, with northern NSW representing the greatest decline in both numbers and distribution (McAlpine et.al 2015). Coastal populations are most at risk and recognition of the importance of coastal habitat within state forests is rapidly growing with koala experts, land managers and conservationists. Lunney et al. (1997) concluded that state forests contain the core of surviving populations in the Eden region of south-east NSW. Andrews et al. (1994) validated this theory when undertaking surveys in the Urbenville Forest Management Area, having recorded koala at more sites than any other arboreal mammal species.

The National Koala Conservation and Management Strategy 2009–14 provided a policy framework which aimed to conserve koalas by retaining viable populations in the wild throughout their natural range. Central to this strategy is the translation of research into effective policy and management actions to arrest the decline of northern koala populations. At the national scale, frameworks such as the National Biodiversity Conservation Strategy 2010–20 and Australia’s Native Vegetation Framework, which are currently being revised, provide a broad policy context for koala conservation. The national koala strategy reflects a number of trends in national conservation that are outlined in these policies, such as encouraging conservation on a landscape scale, and ensuring the effects of climate change are taken into account in conservation planning.

The National Koala Conservation and Management Strategy is a policy document that provides priorities and directions for action. Most of the regulatory control that affects koalas is at the state government level, in the form of planning laws, regulations and regional plans that set frameworks for development and conservation. These rules both enable and limit the capacity of local government to make planning decisions. The integration of national and state koala policies with state and local regulatory decisions is a critical goal to conserving koalas and their habitat. To this end, the EPA Koala Habitat Mapping Project directly aligns with Action 1.02 of the national strategy:

Assess, develop and implement options for protecting priority koala habitat on public lands using legislation, covenants or agreements, or by new acquisition of koala habitat.

1.2 Project objectives

A coordinated koala habitat mapping pilot project was initiated by the EPA Forestry Section.

This pilot study aimed to:

- develop a pilot methodology to identify, classify and map koala habitat on state forests
- trial a number of different koala habitat mapping methods within four pilot areas of state forest under different regional environmental conditions
- produce management scale koala habitat mapping (1:5000) for these four pilot areas
- determine the adequacy of the methods in accurately and efficiently identifying koala habitat for the purposes of managing the impact of native forestry operations.

The following mapping methods were the basis for this comparison and determination:

- plant community type (PCT) mapping
- predictive koala habitat modelling (probability of occurrence)[2]
- forest type mapping, Research Note 17, (RN17) that has been reassigned by DPI to develop likely koala habitat class.

The survey effort included koala activity, (SAT Phillips and Callaghan 2011), plant community type and koala habitat assessment. A comparative analysis of data was undertaken, and was used to produce a series of map-based products to show koala habitat class, koala 'probability of occurrence', generation persistence and habitat utilisation.

[2] The development of the Koala Model was undertaken by an OEH officer in Coffs Harbour employed on a separate project. While not officially sanctioned, the Koala project team took an opportunity to utilise a local resource who was highly experienced in the use of spatial modelling techniques. OEH may further develop the approach at a future time.

2. Pilot study areas

2.1 Introduction

The pilot study areas are situated within the boundaries of the Upper North East and Lower North East regions (Figure 1, over). Table 1 provides the general koala habitat status of each study area.

Koala survey and habitat mapping was conducted across four state forests: Royal Camp (east), Carwong, Maria River and Clouds Creek (part of), which were chosen for their recognised importance in supporting significant koala *Phascolarctos cinereus* population densities and variable habitat conditions.

Table 1: Pilot study areas – area and koala habitat status

State forest pilot study areas	Area (hectares)	General koala habitat conditions
Royal Camp (east portion)	1430	Dry/low to moderate fertility – low carrying capacity – low density population
Carwong	600	Dry/low to moderate fertility – low carrying capacity – low density population
Clouds Creek (southern portion)	2,566	Wet/moderate fertility – moderate to high carrying capacity – moderate density population
Maria River	2,069	Dry/moderate to low fertility – moderate carrying capacity – low density population
Total	**6,665**	

2.2 Royal Camp and Carwong state forests

Royal Camp and Carwong state forests are located to the south of Casino, west of the Pacific Highway on the far north coast of NSW and within the catchment of the Richmond River.

Royal Camp topography varies from flat, low-lying floodplain (eastern section) to undulating foothills (south-western section) and steep, rugged sandstone escarpments (north-western section not surveyed in this study). Elevation ranges from approximately 50 metres in the east to approximately 240 metres in the north-west. The two western sections of Royal Camp were excluded from the pilot as they were difficult to access for survey purposes within the time allocated to the project.

Scotts (2013) identified this koala hub as part of the Northern Clarence and Southern Richmond regional and subregional population. Koala habitat in Royal Camp and Carwong are dominated by woodland/forests on low nutrient meta-sediments supporting *Eucalyptus propinqua, E. molucanna, E. microcorys, E. tereticornis* and *E. glaucina* as preferred koala food trees. This koala habitat is representative of a low carrying capacity/low occupancy koala habitat (Phillips 2013).

Soils in Royal Camp and Carwong are deep, well-watered and relatively fertile in lower parts of the landscape. However, fertility levels were assigned as *infertile* in the vast majority of spot assessment technique (SAT) surveys to place them in context with soils elsewhere in this koala habitat mapping pilot (e.g. Clouds Creek State Forest), where soils are overall of a higher fertility level.

General habitat form throughout Royal Camp and Carwong SFs were classed as *dry sclerophyll/open forest/grassy understorey*. Floodplains are composed of forested wetlands, and major drainage lines are characterised by wet sclerophyll open forest, albeit highly constrained (see Tables 17 and 18, Section 5.3.1).

Carwong State Forest is situated to the south-east of Royal Camp State Forest. It is relatively isolated from public use and is surrounded by private lands including pine plantations and native forests both subject to cattle grazing. Topography is flat to undulating throughout Carwong State Forest with elevation ranging from approximately 50 to 80 metres.

Figure 1: Pilot study areas

2.3 Maria River State Forest

Maria River State Forest encompasses four separate land parcels and is located approximately 10–15 kilometres south and south-west of Kempsey. The Pacific Highway bisects the main forest block.

Most of the state forest is relative undulating with little topographical relief and characterised by many forested wetland drainage channels; the western portion is also relatively flat but drops away to a drainage line to the east of the state forest boundary. General habitat forms throughout Maria River State Forest were classed as *dry and wet sclerophyll/open forest/grassy or heathy understorey* (see Table 20, Section 5.3.1).

Maria River State Forest represents a coastal low-lying blackbutt dominated forest type. The state forest is generally dominated by dry–moderate/low fertility environmental conditions supporting *E. microcorys* and *E. propinqua* as preferred koala food trees. This koala habitat is representative of a moderate carrying capacity / low occupancy koala habitat.

2.4 Clouds Creek State Forest

Clouds Creek State Forest is located near the locality of Dundurrabin approximately 30 kilometres north-west of Dorrigo on the Dorrigo plateau, at approximately 600–650 metres altitude. The terrain is relatively steep.

Scotts (2013) has identified this koala hub as part of the Chelundi–Clouds Creek–West Dorrigo regional population and Chelundi–Clouds Creek subregional population, with a population status is ‘stable’ and of moderate density.

Original perceptions of Clouds Creek were that it represented high productive forest types, generally dominated by wet/high fertility environmental conditions. Clouds Creek State Forest was considered to have potential for a high to moderate carrying capacity. The soils of the pilot area is largely characterised by medium fertility (ASRIS, 2015).

General habitat forms throughout Clouds Creek State Forest were classed as *wet sclerophyll/open forest/shrubby or grassy understorey*. Components of Clouds Creek also contain dry sclerophyll open forest on low fertility soils, rainforest and forested wetland types (see Table 20, Section 5.3.1). General koala habitat conditions are representative of wet/medium soil fertility supporting *E. microcorys* as the preferred koala food tree.

3. Identification of potential koala habitat

3.1 Koala habitat mapping

Koala habitat mapping provides an important basis for identifying and protecting both occupied and currently unoccupied habitat. In order to define the quality and extent of koala habitat it is important to have some understanding as to what elements of the landscape are most utilised by koala (Phillips 2015).

3.1.1 Koala habitat determinates

This project initially followed current Koala Plan of Management methods of habitat identification and classification based on feed tree presence. The expert panel then made a number of recommendations for analysis of data to better qualify where and why koala occupancy occurs. The literature outlines that where koala meta-populations occur (Scotts 2013), 'potential' habitat for koala comprises a relatively small number of food tree species with different foliar chemistry and nutritional value (Hindell and Lee 1987; Lunney et al. 1998; Phillips and Callaghan 2000; Ellis et al. 2002; Smith 2004; Moore and Foley 2005). However, the identification of preferred tree species across large and diverse landscapes can be a complex process, because there are a variety of factors that influence whether or not koalas are present in the first instance. Considerations include the extent of habitat fragmentation, barriers, historical disturbance, disease, predation, stochastic events such as fire, and the nutrient status of the soil (Moore and Foley 2000; Phillips and Callaghan 2000; McAlpine et al. 2006).

Soil fertility, soil moisture and tree size play a major role in the nutritional and water content value of the leaf resource, where both attributes can vary considerably across regional and local scales (Moore et al. 2004; Phillips 2013). In addition to food trees, a range of non-food trees and landscape positions have been cited in the literature as determinates to habitat suitability by providing microclimatic refuges during heatwaves and droughts (Smith 2004; Mathews et al. 2007; Ellis et al. 2010; Crowther et al. 2014). Using preferred food trees alone can lead to overestimating and underestimating potential koala habitat at regional and local scales, potentially resulting in inappropriate land management decisions.

3.1.2 Koala feed tree preferences and habitat classification

The approved NSW Recovery Plan for the Koala (DECC 2008) provides regionally-based lists of primary and secondary koala food trees and directs that food tree use by koalas be thoroughly investigated for a given area. A review of the Koala Recovery Plan 2008 is currently underway in light of more recent scientific understanding of koala ecology.

Phillips (pers. comm. 2015) provided the EPA with a list of koala food trees in Koala Management Areas 1 and 2, based on data from other projects conducted in the Areas. Many trees were listed in the Recovery Plan as 'secondary', however, it can be difficult to distinguish between primary and secondary food trees where they found together.

Consequently, assessment of habitat quality for koalas should be based on the identification of local preferences of species and quantification of the availability of those species (Phillips and Callaghan 2000; Phillips et al. 2000). Within a given area, only a few of the available *Eucalyptus* species will be preferentially browsed, while others, including some non-eucalypts, may be incorporated into the diet as supplementary browsed or utilised for other purposes such as shelter (Lee and Martin 1988; Hindell and Lee 1990; Phillips 1990; Phillips 1999; Phillips et al. 2000, Phillips and Callaghan 2000). In areas of northern NSW east of the Great Dividing Range, tallowwood (*Eucalyptus microcorys*), grey gum (*E. propinqua*), forest red gum (*E. tereticornis*) and swamp mahogany (*E. robusta*) are consistently identified as among the most preferred food tree species (Phillips 2015).

The ability to produce an ecologically-meaningful map of koala habitat is not only dependent upon unambiguous identification of preferred food tree species and soil fertility as a means of categorising habitat in the first instance, but additionally, the detail and underlying accuracy of identifying anthropogenic activities and koala socio-biological function, also needs consideration (Phillips 2015).

3.2 Current ways to classify koala habitat

3.2.1 State Environmental Planning Policy No. 44

Under the NSW *Environmental Planning and Assessment Act 1979*, State Environmental Planning Policy No. 44 (SEPP 44), 'potential koala habitat' refers to areas of native vegetation where the trees that are listed in Schedule 2 of the policy constitute at least 15% of the total number of trees in the upper or lower strata of the tree component. 'Core koala habitat' refers to land with a resident population of koalas, evidenced by attributes such as breeding females and recent sightings as well as historical records of a population. Both definitions have been incorporated into this pilot project as part of the process to identify both potential habitat and koala occupancy over time.

3.2.2 Koala Recovery Plan 2008

Koala classification as defined by the Koala Recovery Plan 2008 (the Plan) is based on a suite of tree species available in any one area that have been determined to be regionally specific primary and/or secondary food tree species. Where primary food tree species are absent or occur in low density, koalas will rely on secondary food tree species, but the carrying capacity of the habitat (i.e. number of animals per hectare) is inevitably lower.

Within a state forest context, koala feed tree availability is affected by habitat disturbance and vegetation community modification. The consequences of misinterpretation of habitat quality and local koala feed tree utilisation are significant. Koala habitat definition is complex, and the application of these in a regulatory setting within state forests makes defining the following options difficult.

Option 1 – Phillips (2002)
Primary habitat Areas of forest and/or woodland wherein primary food tree species comprise the dominant (i.e. ≥50%) overstory tree species. Capable of supporting high density koala populations (≥0.75 koala/ha). **Secondary habitat (class A)** Primary food tree species present, usually (but not always) growing in association with one or more secondary food tree species. Capable of supporting medium density koala populations (≥0.10 koala/ha but <0.75 koala/ha). **Secondary habitat (class B)** Primary food tree species absent, habitat comprised of secondary and supplementary food tree species only. Capable of supporting viable, low density populations (<0.10 koala/ha).
Option 2 - Callaghan (unpublished, cited in DECC 2008)
Primary habitat Areas of forest or woodland where primary koala food tree species comprise at least 50% of the overstory trees. Capable of supporting high density koala populations.

Secondary habitat (class A)

Areas of forest or woodland where primary koala food tree species comprise less than 50% but at least 30% of the overstory trees; or

Areas of forest or woodland where primary koala food tree species comprise less than 30% of the overstory trees, but together with secondary food tree species comprise at least 50% of the overstory trees; or

Areas of forest or woodland where secondary food tree species alone comprise at least 50% of the overstory trees (primary koala food tree species absent).

Capable of supporting high to medium density koala populations.

Secondary habitat (class B)

Areas of forest or woodland where primary koala food tree species comprise less than 30% of the overstory trees; or

Areas of forest or woodland where primary koala food tree species together with secondary food tree species comprise at least 30% (but less than 50%) of the overstory trees; or

Areas of forest or woodland where secondary food tree species alone comprise at least 30% (but less than 50%) of the overstory trees (primary koala food tree species absent).

Capable of supporting medium to low density koala populations.

Secondary habitat (class C)

Areas of forest or woodland where koala habitat is comprised of secondary and supplementary food tree species (primary koala food tree species absent), where secondary food tree species comprise less than 30% of the overstory trees. Capable of supporting low density koala populations.

Tertiary habitat

Areas of forest or woodland where primary and secondary koala food tree species are absent, but which have important supplementary koala habitat values such as habitat buffers and habitat linking areas. Such areas are considered to be necessary components of habitat for the overall conservation of koala populations. Not capable of supporting koala populations in the absence of primary or secondary habitat.

Option 3 - Phillips 2015 has since updated this classification as follows.

Primary koala habitat

Forest and/or woodland communities occurring on soils of medium to high nutrient value whereupon primary koala food tree species are dominant or co-dominant (i.e. ≥50%) components of the tallest stratum species.

Secondary (Class A) koala habitat

Forest and/or woodland communities occurring on soils of medium to high nutrient value whereupon primary food tree species are sub-dominant components of the tallest stratum species.

Secondary (Class B) koala habitat

Forest and/or woodland communities occurring on soils of low to medium nutrient value whereupon primary food tree species are absent, the tallest stratum dominated or co-dominated by secondary food tree species only.

Secondary (Class C) koala habitat

Forest and/or woodland communities occurring on soils of low to medium nutrient value whereupon primary food tree species are again absent and secondary food tree species are sub-dominant components of the tallest stratum species.

3.2.3 Koala plans of management

Some local government Koala Plans of Management (KPoMs) have applied a collective term ‘preferred’ to koala classification based on the Plan’s categories (see Table 2). This approach is an acknowledgement that koalas are distributed largely across all classes and that local councils do not have an array of land management options to protect koala within a Local Government Area (LGA) (Turbill pers. comm. 2015). One of only two outcomes is usually the result; clearing an area for development (with or without an offset or supplementary tree retention/planting) or not. Single classification of suitable habitat supported by occupancy data may help to address issues of mismanaging koala habitat.

Table 2: Bellingen KPoM koala habitat classification

Vegetation classified as ‘preferred’ koala habitat	Primary	Vegetation associations and/or communities wherein ‘primary’ food tree species form ≥50% of the canopy.
	Secondary A	Vegetation associations and/or communities wherein: • ‘primary’ food tree species form 30–50% of the canopy, or • ‘primary’ and ‘secondary’ species combine to form ≥50% of the canopy.
	Secondary B	Vegetation associations and/or communities wherein ‘secondary’ food tree species form ≥50% of the canopy.

3.2.4 EPA potential koala habitat classification on state forest

Koala habitat determinates

Identification of koala habitat within a state forest context is complex and at the local scale. Disturbance is largely homogenous over this tenure due to forest management regimes and the associated influence on forest ecology and the natural expression of vegetation types. Fertility assessment does not inform this classification as the areas are small and fertility is largely homogenous, albeit greater in lower parts of the landscape. Therefore, this classification cannot be based on fertility components in state forests, nor does it assist in improving recognition and protection of significant low-density populations in dry and infertile areas.

EPA koala habitat classification

With the current classification processes reviewed, the EPA and the expert panel has made the following deductions for koala habitat assessment in a state forest context.

Local koala feed trees

Local koala feed trees are identified at the local (state forest) or subregional scale (predetermined via koala surveys undertaken for other purposes). Many species listed as secondary in the Plan (2008) are regional and little data is available to supports their use independent of primary feed trees. Where these species are present in the pilot areas and tree use is significantly lower than primary tree species, they are seen as habitat associates of vegetation communities where local feed trees have been identified. A large subregional or local dataset is required to determine preferences as trees in close proximity to known feed trees can appear to be feed trees, as opposed to habitat trees.

The need for an inclusive potential habitat classification

Vegetation classes previously mapped by Forests NSW Research Note 17 (RN17) under the Threatened Species Licence 1995 and local government area koala plans of management, indicated that minimal 'primary' habitat had spatial currency and was not reflecting koala occupancy and landscape distribution. This is also the case for Koala Plans of Management and is reflected in the move towards merging both primary (>50% KFT) and secondary A and B (>30<50% KFT primary and secondary combinations) habitat into the 'preferred' habitat classification. This spawned the understanding that although koalas may prefer better quality habitat and activity may be greater in these habitats at the site-scale, high numbers of koala are still present throughout secondary habitat types, and it is these types that have the greatest spatial cover at the landscape-scale.

At the site scale, higher koala occupancy correlates with higher quality habitat (primary) as feed tree abundance, diversity, and soil fertility and moisture increase (Lee 1987; Lunney et al. 1996; Smith 2004; Phillips 2013). The local or subregional scale classification of koala habitat and the determination of tree utilisation is of great significance as current classifications can be misinterpreted or misused in land management. For example, koala habitat in Royal Camp State Forest could be classified as secondary B by the Plan and RN17 mapping, as primary feed trees presence is generally less than 30%, grey gum and grey box are listed as secondary food trees and soil fertility and moisture is low to medium. Current koala findings (Phillips 2013) for Royal Camp indicate that koala habitat is supported by dry woodland/forest on low nutrient meta-sediments. The forest types supported by these environmental conditions sustain low density numbers of koala (Phillips 2013). Under this current classification, land managers would deem this habitat as secondary B and by comparison to 'primary' habitat, gravitate towards limited protection. Similar responses are seen within management of koala habitat in local government areas, where 'primary' habitat protection is favoured over secondary classified habitats such as that for development approvals and property vegetation management plan outcomes.

Local and subregional habitat variation and significance to koala

Forest types in dry, infertile areas cannot be compared with higher fertility and wetter environments such as those areas supporting higher density koala populations in other parts of the state (Tweed, Coffs Harbour, Port Macquarie and Port Stephens) as soil fertility, moisture gradients, climatic variables and koala feed tree nutrition and density differ markedly. Recent research has highlighted regional variation in habitat–occupancy thresholds (Rhodes et al. 2008) and warned against applying general rules across different landscapes.

In a subregional context where dry and low fertility environmental conditions dominate, such forest types exhibiting koala activity greater than 10% are considered 'optimal habitat occupancy' (Phillips 2013) and therefore require a classification to adequately protect koalas in this context.

For the purposes of identification and regulation of forest operations to protect koala habitat, it was recognised that a simplistic, quantitative classification was needed. This classification needed to recognise local variation in potential habitat, local koala feed trees and the significance of low density populations within dry and infertile landscapes. The approach is based on the need for easy assessment and regulation methods that recognise the minimal protection afforded to koala habitat that is not classified as 'primary' habitat across all tenures. To address the level of threat to koala populations within a state forest context, the expert panel and the EPA developed a classification that departs from the combination of quantitative and qualitative descriptions listed in the Koala Recovery Plan (2008) and above in Section 3.2.2, and adopts a classification that is precautionary. The classification combines the primary and secondary A classes into class 1 and uses local koala food tree (LKFT) utilisation as primary drivers to define habitat class. Other determinates listed as koala determinates (disease, predation, socio-biological factors) are out of scope for this project.

For use in the context of classifying, identifying, mapping, protecting and regulating koala habitat on state forest estate, the EPA has adopted the following potential koala habitat classification agreed to by the Panel in 2015 (Table 3).

Table 3: EPA potential koala habitat mapping classification

Koala habitat classification	
Greater than or equal to 30% local koala feed tree species	Class 1
Greater than 15% but less than 30% local koala feed tree species	Class 2
Less than 15% local koala feed tree species	Class 3
Local koala feed tree species absent	Non habitat

4. Method

Koala survey and habitat mapping was conducted across four state forests: Royal Camp (east), Carwong, Maria River and Clouds Creek (part of). These locations were chosen for their recognised importance in supporting significant koala *Phascolarctos cinereus* population densities and variable habitat conditions.

For this pilot project, priority koala habitat was identified by undertaking 3D ADS40 interpretation (3Ai) of plant community types (PCTs) to derive a koala habitat class map.

A modified spot assessment technique (SAT) for koala scat searches was undertaken to determine koala occupancy and habitat utilisation.

A comparison of mapping methods was then undertaken using modelled and existing vegetation mapping resources to determine the efficacy of using a koala habitat map to protect koala populations.

The validation of results through assessment of koala class mapping, carrying out spotlight survey and utilising a koala detection dog.

4.1 Potential koala habitat

The core objectives of this project included the development of a pilot methodology to identify, classify and map Koala Habitat on state forest, and a management scale koala habitat map for the four pilot areas.

4.1.1 Habitat mapping

The project compared the efficacy of three potential koala habitat identification methods:

1. 3Ai-PCT mapping (recently undertaken for the pilot areas)
2. Reassigned Research Note 17 (RN17) into likely koala habitat class
3. Predictive habitat model (probability of occurrence (POC)).

3Ai-PCT mapping

Mapping of plant community types (PCTs)

Vegetation patterns were mapped using an advanced 3D mapping environment. PLANAR stereo viewers together with Stereo Analyst for ArcGIS software were used for this purpose. Field survey for PCT floristic and structure composition was conducted within a homogenous representation of a polygon and data captured using FULCRUM forms on tablet devices (Appendix B provides an example of the field form). Appendix A contains mapping definitions such as minimum dimensions for polygon size, reference scale, variant criteria, and other features mapped as part of the process, such as structure, fertility and disturbance.

Assignment of koala habitat class to plant community type map

The Koala Recovery Plan (DECC 2008) identifies two options for mapping of koala habitat and Phillips (2015) offers another option to include soil fertility. These techniques primarily rely on assessing what proportion of the forest canopy is composed of koala feed trees. These techniques were further refined for this project and are presented in Appendix C (PCT and KH assessment form). Table 4 describes the feed tree composition for stage 1 of koala habitat mapping.

Table 4: Mapping specifications for koala habitat classes

Koala habitat classification	
Greater than or equal to 30% local koala feed tree species	Class 1
Greater than 15% but less than 30% local koala feed tree species	Class 2
Less than 15% local koala feed tree species	Class 3
No local koala feed tree species or non-eucalypt PCTs	Non habitat

Using these criteria, koala habitat was assessed in the field, transferred and mapped by 3Ai for each native vegetation polygon in the study area.

Canopy variance within plant community types

Current Koala Plans of Management estimation of koala class for each polygon is generally driven by the plant community type profile description, which is based on Fidel diagnostics and analysis (Appendix D). Some plant community types experienced significant variation in canopy tree expression. Where possible, this variation was recorded during the 3Ai mapping process. As a guide, variants were recorded where a polygon was found to be dominated or co-dominated by a species not listed as being a major species for that plant community type or where a non-listed koala feed tree was present at >15% cover.

Koala class was initially determined using the Fidel diagnostics of frequency of occurrence and canopy cover scores for the various vegetation types listed in the *Vegetation Classification for the Northern Rivers Catchment Management Area of New South Wales* (OEH 2012). Appendix D (Fidel KC calculation example) outlines this calculation to determine relative abundance of feed tree canopy by the total canopy. The canopy cover for each species was moderated by its frequency of occurrence in a plant community type. Floristic data from the 3Ai mapping and field koala habitat assessment surveys were used to validate this process and was a basis for not using Fidel to derive habitat classes.

RN17 mapping

Derivation of koala class from RN17 forest type mapping

RN17 forest type mapping (Forestry Commission of NSW 1989) has been completed for each of the pilot study areas. A recent DPI/EPA review of RN17 types as recommended by the expert panel has resulted in a refinement of the assignment of koala habitat classes (Appendix E). This reassignment of RN17 types has been undertaken by direct assignment of type class to ‘likely occurrence of koala within types’. This assignment was undertaken using interpretive techniques based on abundance of known koala feed trees and also analysis of the recorded occurrences of koalas in each mapping type. These were used to assess each pilot area for its vegetation assemblage diversity against 3Ai and its relevance to identifying potential koala habitat and priority koala habitat based on koala occupancy data.

Modelled habitat

The pilot project assessed the potential for koala habitat modelling to accurately predict the probability of occurrence (POC) of koala and quality of potential koala habitat in NSW state forest native vegetation. A Niche-Based Distribution Modelling of Koala Habitat (predictive habitat model) has been developed for this purpose, in addition to providing a habitat layer upon which to base stratified koala occupancy sites.

Predictive habitat model

A process to model the probability of occurrence of koala using presence and absence data was undertaken in 2014. The initial draft product was used to stratify the spot assessment technique sites and to assess the model outputs correspondence with koala activity data.

The methodology employed in the development of the draft koala habitat model (Appendix I) includes only abiotic predictors (climatic, topographic and fertility) around known koala records. Absent sites were derived from using NSW Vegetation Information System data and a list of known koala feed trees and known koala records. The raw model product exists as a range from 0–1, with 0 being lowest prediction and 1 being highest. This range was expertly converted to a five category class map for display and analysis purposes. The categories of probability of occurrence are shown below in Table 5.

Table 5: Predictive habitat model – thresholds for five levels of probability of occurrence (POC)

Class	Code	Lowest value	Highest value
Very high POC	1	0.9505	0.9698
High POC	2	0.9017	0.9477
Moderate POC	3	0.8065	0.8993
Low POC	4	0.4103	0.7916
Predicted absent	5	0.0237	0.3932

For stratification of sites and some analytical purposes, classes 1 and 2 (very high and high) were merged, as were classes 4 and 5 (low and predicted absent). All five classes were used for assessment of habitat and comparison with SAT data.

4.1.2 Comparison of habitat mapping methods

Comparison of vegetation (plant community type (PCT) versus RN17)

Vegetation community (or type) mapping is seen as fundamental in underpinning mapping of potential koala habitat by many experts. Its accuracy in reflecting both the diversity and location of vegetation assemblages and therefore koala habitat quality is a significant step in identifying priority koala habitat. 3Ai-PCT mapping and RN17 mapping were seen as two viable alternatives for fine scale mapping of koala habitat. It was seen as a useful exercise to compare the outcomes of both methods within the pilot areas if either was to be considered as a basis for koala habitat mapping.

Correspondence of 3Ai mapped koala habitat with modelled probability of occurrence

The modelled categories were overlain with the 3Ai mapped habitat classes as a level of validation of the model and the co-incidence of these classes was measured. This process was seen as useful given the high degree of effort placed on field validation of the 3Ai mapped classes. The tabulate areas function in ArcMap Spatial Analyst was used to calculate the coincidence of classes in the respective datasets. A resolution of 25 metres was set for this purpose.

Using these three alternative scenarios of koala habitat, the mapped area and relative proportion of each recognised koala habitat class was calculated. Using map overlay in ESRI ArcMap, area values for each pilot area were calculated and represented in the figures. Royal Camp State Forest and Carwong State Forest have been combined for reporting purposes.

4.2 Koala occupancy

4.2.1 Survey techniques

The standard spot assessment technique (SAT) method

Two survey effort activities were carried out, one by contractors guided by the Predictive Habitat Model, and the other by EPA Operations staff and Forestry Corporation of NSW (FCNSW), guided by a 500 metre grid across the pilot areas. A modified spot assessment technique (SAT) method of Phillips and Callaghan (2011) was applied to SAT surveys undertaken in the pilot areas. Maria River State Forest was excluded from this survey effort due to time constraints and was therefore only subject to model stratification sampling. The results of koala activity for Maria River State Forest reflect this reduced survey effort.

The standard SAT method is a point-based, tree sampling procedure that utilises the presence/absence of koala faecal pellets around the base of trees greater than 10 centimetres diameter at breast height (dbh) to derive a measure of koala activity (Philips and Callaghan 2011). Thirty trees were sampled comprising a ‘centre tree’ around which the survey plot was to be undertaken, and the nearest 29 trees to the centre tree. Concentric selection of the 29 trees provides a plot of variable size depending on the density of trees at the site. The plot area was recorded, as were the 30 trees identified to species (or a broader description of ‘tree type’ in this study – see below), and their diameter at breast height was recorded as a measure of overall tree size and age. Phillips and Callaghan (2011) present three criteria for selection of the centre tree. As this project was also validating koala class assigned via plant community type mapping and modelled habitat, the nearest tree to the site was used if no feed tree was available, in order to validate non habitat sites.

Strike rate tree data that supported independent browsing provided the initial predetermined local koala feed tree list (Phillips, S. pers. comm. 2014) used as the basis for habitat classification assessment within the pilot areas as follows:

- small-fruited grey gum *Eucalyptus propinqua*
- red gum species including forest red gum *E. teretecornis* and slaty red gum *E. glaucina*
- grey box *E. moluccana*
- tallowwood *E. microcorys*
- swamp mahogany *E. robusta*.

In the absence of scat dietary analysis, SAT survey methods can be used to build on local tree utilisation where analysis determines significant use of other species spatially independent of these known local feed trees.

Spotlighting

In conjunction with spot assessment technique survey effort spotlighting for koalas was also utilised as a validation survey technique. Up to eight hours (two persons) per state forest area was required. Two methods were utilised during the survey: spotlighting on foot and vehicle based effort.

On-foot spotlighting transects were of a minimum of 250 metres by two people for 20 metres on each side of a transect (1 hectare sample effort per 250 metre length). A 1% sample per pilot area was required, resulting in 20 hectares per 2000 hectare pilot survey undertaken. Spotlighting was restricted to roads and fire trails as generally this is the most efficient and effective method in forested areas.

4.2.2 Field data capture

An electronic data input program (FULCRUM) via tablet devices was used for data capture. Forms were developed by the EPA (Appendix B and Appendix F). For SAT site assessment, contractors recorded tree species. Codes were assigned to tree species and tree types (combinations of species such as red gums, mahogany and rainforest) to assist EPA staff with identification (Appendix F). Data was then downloaded into pdf or Excel for further analysis.

4.2.3 Site stratification

Modelled based stratification spot assessment technique (SAT) site selection

The term 'modified' SAT reflects the way sites were initially selected for this survey. Contractor site selection involved a stratification process, undertaken by the EPA based on the predictive habitat model.

Forty sites were required to be sampled within a nominal 2000 hectare area of each state forest pilot area. Selection of sites took into account available road access and a proportional spread relative to the habitat classification assignment across the pilot area. For site stratification purposes, probability of occurrence (POC) classes were grouped (see Table 6) to allow for more discrimination between habitat quality and to reduce sample effort due to time constraints.

Sites were allocated according to area of koala habitat class predicted by the habitat model POC classes. The sampling was weighted to more heavily sample POC classes which are more extensive on an area basis, as seen in Table 8.

Table 6: Model based stratification design – SAT site distribution by POC and state forest

	Probability of occurrence class							
State forest	**1**	**2**	**1 and 2**	**3**	**4**	**5**	**4 and 5**	**Total**
Royal Camp	16	8	24	1	10	10	20	45
Carwong	7	11	18	1	1	0	1	20
Maria River	15	9	24	15	5	1	6	45
Clouds Creek	21	24	45	8	6	1	7	60
Total sites	59	52	111	25	22	12	34	170
Koala bioclime			1	2			3	

Value thresholds for POC were established on the basis of fitted value analysis of presence/absence record data to indicate perceived habitat value and suitability to koala.

Grid based spot assessment technique (SAT) site selection

EPA and FCNSW staff used the same SAT forms to capture data as the contract teams. Survey effort was governed by the 500 metre grid across pilot areas. Sites that were within 100 metres of a stratified site were excluded to save time and reduce compounded results.

4.2.4 Records analysis

The occupation mapping utilises filtered records of koalas to populate the spatial model, so is reliant on survey effort. In this respect, the analysis has a tendency to be skewed toward more populated areas (where koalas are more likely to be observed) and lands regularly surveyed (e.g. state forests). Remote Crown lands and private lands have a tendency to be under-surveyed and therefore are not well represented in the modelled data.

Site analysis

3Ai field koala habitat assessment

3Ai field data was exported from FULCRUM as Excel spreadsheets. A rapid koala habitat assessment method (Appendix C) was developed to identify koala habitat classes from the total projective foliage cover (PFC) of all species present from which koala food trees are identified. The PFC percentage sum of koala feed tree is expressed as a percentage of the total projective foliage cover of the canopy within a 50 metre view shed radius site (0.79 hectares). This dataset formed the basis of koala class classification within and across PCT-mapped polygons. The 3Ai derived habitat classes were also used to analyse the validity and practicality of RN17 and modelled koala probability of occurrence. Finally, these classes were correlated against spot assessment technique data to determine the suitability of koala habitat mapping as a surrogate for protecting areas of koala occupancy.

Spot Assessment Technique (SAT)

SAT data was exported from FULCRUM as Excel spreadsheets of site data and tree data within sites. The two datasets (grid-stratified and model-stratified) were combined for the purposes of tree data analysis and validation of occupancy within koala habitat. Some data points were excluded where they were adjacent (duplicates) or because of data deficiencies (fewer than 30 trees surveyed).

In the course of the SAT surveys, validation of scat identification was undertaken. Where there was uncertainty about the type of scat identified, a sample was taken on site and retained for later validation by EPA and OEH officers.

A proportion of these samples (koala and not koala) were sent away for formal examination by Barbara Triggs, scat analysis expert, as further confirmation (Appendix G). Validation of koala scat presence for a subset of sites within each pilot area was also undertaken by a koala detection dog (Appendix K).

Activity by koala class

For correlation analysis purposes, only SAT sites assessed as resident (Table 7) were used to validate the efficacy of koala habitat categories. This decision was made on the advice of the Panel in July 2015 to only analyse data sets where koala were truly active and not potentially transient. Both the low density populations of the study areas and recent findings from other Koala Plans of Management reflecting generally low activity levels across potential habitat (Coffs Harbour, Nambucca and Bellingen LGAs) supported this approach. As a precautionary measure, SAT sites assessed as 'present' only were included when within 500 metres of a resident site, as it is more likely to be the same koala or one sharing the resident home range.

Table 7: SAT activity classes for correlation analysis

SAT activity level	Description
Resident	>10% activity (or 3.3–10% activity within 500 m of a site with >10% activity)
Present	<10% activity
Absent	0

The distribution of the SAT activity in each of the pilot areas can be seen in maps presented in the habitat mapping results (Section 5.2).

Tree utilisation

Activity strike rate and species preferences by state forest area

Key questions arising from the SAT activity data relate to the preferencing of species by koalas: Which trees are utilised by koalas when they are present in an area, and how strong is this preferencing? The expert panel suggested further analysis of tree strike data be undertaken to determine primary use of tree species and size class. Calculating the strike rate for tree species at active sites (sites with at least one tree being utilised) is a useful measure to determine preferencing. The strike rate for a species is the overall proportion of trees which have evidence of koala usage.

Species size class variation with activity

Size class (diameter at breast height) influences the utilisation of trees by koalas (Phillips 2013 and Smith, 2004) and is an important factor in the identification of habitat utilisation and protection conditions that may include retention of habitat or trees at a landscape or site scale. In order to assess whether there is a preference for tree size at a species level, tree size data were assembled for each state forest area. Scat activity data were pooled into size classes in Excel and used to compare activity associated with tree size class and species for individual pilot areas. Linear regression analysis and test of independence (chi-square test) was undertaken for key utilisation species in pilot areas, to investigate the relationship between size class and utilisation by koala.

In undertaking these analyses, the limitations of small datasets were observed. A minimum sampling unit of five observations was set and size classes below this threshold were pooled. Accordingly, many of the larger size classes (above 600 millimetres) were grouped for most species investigated.

Correlation of feed tree data with SAT activity

The weak relationship between koala activity and mapped habitat classes (3Ai mapped, RN17 and modelled POC) was identified. Subsequently, it was decided to investigate the relationship between feed trees and SAT activity at a site level.

One way of doing this was to calculate the correlation coefficient for the total feed trees within a SAT (0–30) and the activity (0–100). A check for data integrity was made before running the correlation. Several sites were excluded from the analysis due to data inconsistencies; issues included wrong location (some sites outside the study area) and sites with fewer than 30 trees.

Landscape analysis

Generational persistence

Generational persistence analysis was used to help understand the long-term persistence of koala populations across the study area. It uses the approach of overlaying a two kilometre grid (400 hectares - normal koala dispersal distance is cited to be from one to three kilometres) across the study area and noting where records for each koala generation (six-year period) are represented.

From this assessment, cells are identified where koala records for a number of generational periods are present. Results using a number of generational periods including from two generations (12 years), three generations (18 years) and four generations (24 years) were used. Koala persistence over a number of generational periods provides an indication of where koala populations have been maintained in the landscape over time. The cells indicate both key areas of continual occupation by koalas and a regional indication of distribution. After a vetting process to remove duplicate and unreliable records, records were then sorted into chronological order and assigned to the last four koala generational periods.

The usual assessment for determining koala generational persistence, in line with the International Union for Conservation of Nature (IUCN) criteria for assessing perceived population declines over a time period of three generations (IUCN SPS 2001), was not practical given the low number of records in some periods compared to the later period 1996–2015. In the absence of a more comprehensive survey dataset from all time periods, limited observations can be made. However, the precautionary principle and logic demands that this is seen as an absence of survey effort rather than an absence of koala persistence.

Potential habitat utilisation

Kernel density analysis (KDA)

The kernel density analysis (KDA) is a visualisation tool in ArcMap which helps to interpolate point data (in this case SAT activity) into a modelled surface. The kernel density analysis is a neighbourhood generalisation tool for point-based sampling. The analysis helps to more clearly discern patterns in point-based data by interpolating gradient values over an established neighbourhood search area. For the koala SAT activity, the most appropriate neighbourhood search zone was determined to be 500 metres, a conservative estimate of a 20 hectare home range for low density koala populations typified by the pilot koala habitat areas. The analysis was employed to give a broader, more generalised understanding of koala potential habitat utilisation based on surveyed activity data.

This analysis is sensitive to clustering of records. For this reason, the SAT activity records were manually edited to remove adjacent records or potential overlapping home ranges (although female koalas overlap), so a precautionary tolerance of a 300 metre exclusion of records was applied. In order to augment (gap fill) SAT activity data, recent ATLAS data (within the last 12 years to reflect the average lifespan of a koala) was also included and given an activity level of ‘present’ (3.3%). The output of the kernel density analysis is a model of continuous values which have been pooled into two classes to replicate the familiar ‘resident’ and ‘present’ classes used to classify the SAT site activity data. These classes were further divided into high and low to provide further discrimination of the data to reflect habitat utilisation as in Table 8.

Table 8: Utilisation by kernel density – output classes

Kernel density class	Description
0 – 1.66	Absent / negligible
1.67 – 5.00	Present – low activity
5.01 – 10.00	Present – high activity
10.01 – 20.00	Resident – normal activity
20.01 – 40.00	Resident – high activity

The analysis results have been presented as utilisation ‘activity’ and represent an interpolation or localised ‘model’ of koala occupancy and habitat use within the pilot state forest areas where sufficient ground survey has been undertaken.

The kernel density map was overlain with habitat mapping as a form of validation or ‘agreement’ with mapped habitat classes and assumed occupancy. While the kernel density analysis has no statistical value, it is useful for visualising a koala’s potential spatial use of habitat resources beyond a single map based data point and helps to show the correspondence between ground survey data and mapping.

Table 9: Specifications of kernel density analysis

Kernel Density Tool (Spatial Analyst, ArcMap 10.3)	
Input point data:	SAT site data (EPA stratified and grid) and Clean ATLAS data (<12yo)
Population field:	SAT activity
Output raster:	Kern_500_200
Output cells size:	125m (resolution of output data)
Search radius:	500m (to reflect conservative estimate of low density population home range of 20ha
Area units:	hectares
Output values:	expected counts

Habitat determinates

The expert panel made recommendations regarding further analysis of habitat determinates that impact on koala occupancy, to attempt to explain koala activity across the landscape.

Fertility

Fertility layers were reviewed at the landscape scale for all pilot areas using online CSIRO soil fertility layers (ASRIS, 2014). Both data forms for SAT and PCT survey required a fertility description to be completed to assist in the assessment of koala habitat quality. This descriptor was included on the basis of literature defining fertility as a major factor in qualifying koala habitat quality and preferencing (Reed and Lunney 1990; Phillips 2015), with the hypothesis that koala are limited by availability of nutrients (protein, water and energy) and anti-nutrients (fibre and toxins) in food selection (Moore and Foley 2000). Desktop analysis of this layer against the pilot areas described minimal discrimination across the pilot areas and was therefore determined to be too homogenous to include in any analysis.

Structure

Structure and tree size was considered and recorded in both survey efforts as the literature identified higher tree size class preferences favoured koala occupancy (Lee and Martin 1988; Lunney et al. 1996; Smith 2004; Phillips 2013). The general age structure of the forest was recorded into three categories reflecting the dominant tree maturity component of mapped polygons (Appendix A). Structure was pursued for analysis as it could be confidently discriminated in the field and mapped.

Disturbance

Logging and fire were considered and recorded in both survey efforts as they are cited in the literature as significant disturbance events that affect habitat quality, availability and continuity (McAlpine et al. 2006, 2007; Smith et al. 1995; Smith 2004; Starr 1990; Melzer et al. 2000; Lunney et al. 2007). Logging and fire history was sorted into five-year periods and displayed in Maps 22-24. Limited interpretation can be made as the exact harvest area or logging intensity could not be obtained. Therefore the management regimes applied to these small areas of forest rendered disturbance as relatively homogenous and unsuitable for analysis. FCNSW logging history and fire data was used to gain a landscape perspective of past logging and fire events within all pilot areas.

4.2.5 Efficacy of koala habitat mapping

One of the core objectives of this project was to determine the adequacy of the methods in accurately and efficiently identifying koala habitat for the purposes of mitigating and regulating the impact of native forestry operations.

Koala SAT results were used to determine if mapping of potential koala habitat could be used as a surrogate to protect koala in state forest. Three different scenarios were compared by overlaying SAT data with mapped koala habitat categories:

1. Habitat classes interpreted from digital 3Ai of PCT and koala feed trees
2. RN17 reassigned likely koala habitat class
3. Predictive Habitat Model

The three koala activity classes defined in Table 10 were then used as a basis for reporting habitat classes across 3Ai, RN17 and probability of occurrence.

Table 10: Koala activity thresholds for the study area

Koala activity threshold	Activity level
Resident – high	Evidence >20%
Resident – normal	Evidence 10–20%
Present – low	Evidence <10%

3Ai-PCT mapping

Validation of 3Ai habitat class by spot assessment technique (SAT) activity

The project assessed the potential for 3Ai-PCT mapping to identify koala occupancy in the crown forest estate. SAT activity classes were overlain with 3Ai mapped koala habitat classes in order to test the relationship between koala activity and 3Ai assigned koala habitat class. The SAT activity classes (for both grid and stratified datasets) were intersected with mapped koala habitat classes in ArcMap then exported to Excel and charted.

RN17 mapping

Validation of RN17 habitat class by SAT activity

The project assessed the potential for RN17 mapping to identify koala occupancy in the crown forest estate. SAT activity classes were overlain with RN17 mapped koala habitat classes in order to test the relationship between koala activity and RN17 defined koala habitat classes. SAT activity classes (for both grid and stratified datasets) were intersected with mapped RN17 koala habitat classes in ArcMap then exported to Excel and charted.

Modelled probability of occurrence (POC)

Correlation of modelled POC with SAT activity

The project assessed the potential for koala POC modelling to identify koala occupancy on state forests. As a quantitative measure of reliability, a correlation co-efficient was calculated to determine the strength of the relationship between SAT activity and modelled POC. ArcMap 10.3 – Spatial Analyst was used to generate data pairs with SAT activity and modelled POC. This dataset was imported to Excel and a correlation co-efficient generated using the CORREL function. A total of 57 pairs (across four state forest areas) were used in the correlation analysis including all the current SAT data available from the recent surveys, both stratified and grid data. Some SAT sites were excluded because they were duplicates or fell within the same grid cell in the model. In these cases, the highest activity site was retained.

5. Results

5.1 Stratification and survey

The survey method and results are based on the predictive model stratification effort undertaken by contractors (Scotts, 2015, Fauna Sonics, 2015).

5.1.1 3Ai mapping

Of the 6000 hectares mapped, 2000 hectares were field assessed via sites and vehicle traverse to assess plant community type (PCT) and koala habitat class. Thirty PCTs were identified of which approximately 3000 hectares were mapped as a variance of a PCT.

5.1.2 SAT

A total of 117 model stratified sites and 137 grid stratified sites were surveyed across the four study areas (Maria River State Forest excluded due to time constraints). From these datasets, 19 sites were excluded leaving 111 model stratified sites and 124 grid stratified sites. Eight more model stratified sites were effectively excluded from some aspects of the analysis because they were undertaken in the western block of Royal Camp State Forest, for which no PCT mapping exists, leaving 227 SAT sites for initial analysis.

5.1.3 Predictive model stratification survey outcome – site survey by state forest and probability of occurrence (POC)

The stratification generally achieved a good spread of sites across POC classes. The high probability of occurrence in some state forest areas (e.g. Carwong State Forest) made it impossible to sample effectively across all POC classes. The low outcome of POCs 4 and 5 in Royal Camp State Forest was largely due to the incomplete sampling in the western block, which was restricted by access constraints.

Table 11: Number of sites in POC classes across the study areas

State forest	Probability of occurrence class (POC)							
	1 (Very High)	2 (High)	1 and 2	3 (Moderate)	4 (Low)	5 (Absent)	4 and 5	Total
Royal Camp	9	4	13	2	4	4	8	23
Carwong	4	10	14	3	0	0	0	17
Maria River	12	8	20	10	5	1	6	36
Clouds Creek	18	12	31	3	2	0	2	36
Total	43	34	78	18	11	5	16	111

As a cross-reference and comparison, the distribution of model stratified SAT sites was plotted against 3Ai assessed koala habitat classes. The results give an indication of the confidence with which koala class can be stratified and assessed using current POC models. The results are shown below in Table 12.

Table 12: SAT site survey – 3Ai assessed koala habitat class across the study areas

State forest	Koala class 1	Koala class 2	Koala class 3	Non habitat	Not assessed	Total
Royal Camp	1	8	6	1	7	23
Carwong	8	8	1			17
Maria River	6	9	12	9		36
Clouds Creek	17	8	11			36
Total	31	33	30	10	7	111

Seven sites not assessed in Royal Camp State Forest are those sites undertaken in the west block for which there is no 3Ai assessed koala habitat class mapping.

5.2 Potential koala habitat

Summary

- 3Ai-PCT mapping had the greatest detail of line work and identified a higher diversity of vegetation types.
- Despite this, it was not possible to consistently assign accurate koala habitat classes to mapped PCTs due to variation in canopy species, a factor which is amplified in disturbed forests.
- RN17 mapping grossly simplified koala habitat class, but may be suitable to distinguish suitable habitat from unsuitable habitat.
- A discussion about the suitability of these methods for application at a state forest management scale is in Section 8.

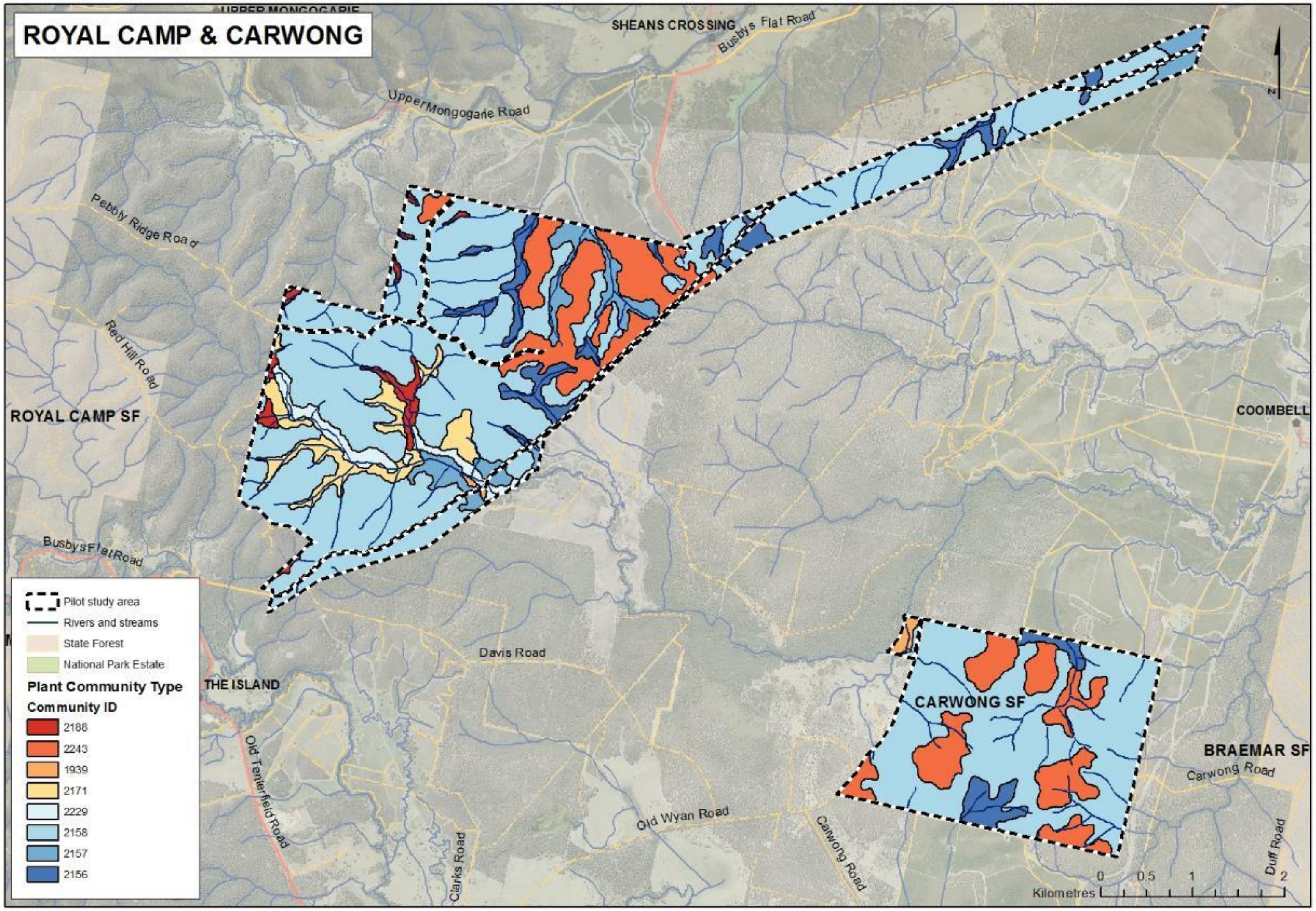
5.2.1 3Ai-PCT mapping

3Ai identified the following hectares of potential koala habitat:

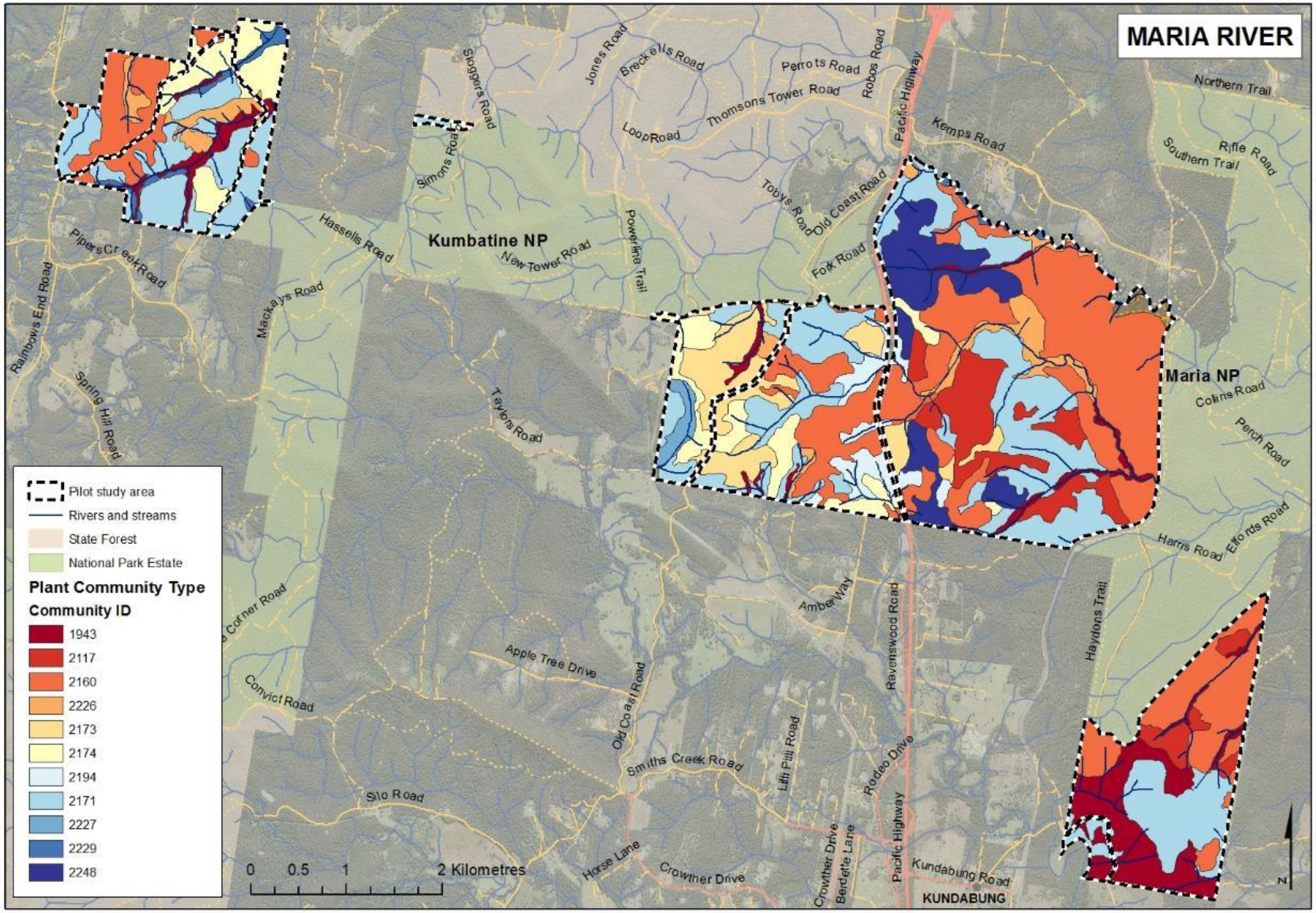
Koala Class	Area (Ha)	% of Pilot Area
1 (LKFT >30%)	1561	23
2 (LKFT <30 >15%)	2120	32
3 (LKFT <15%)	2092	31
Non habitat (non eucalypt veg.)	878	13

The classification was supported by 131 field data points. A list of the 30 plant types (PCT) identified and mapped within the four pilot areas is included in Appendix H.

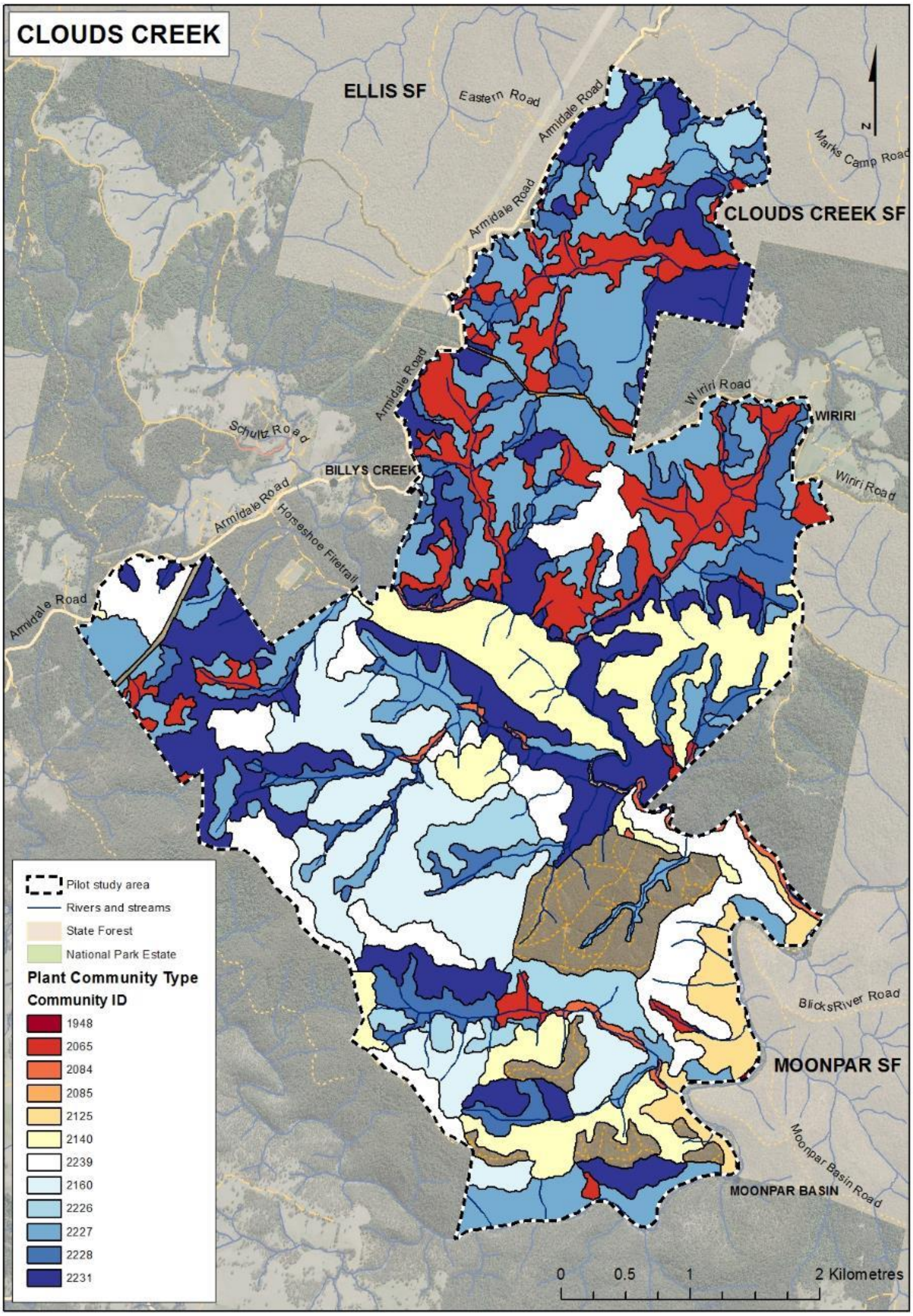
The 30 PCTs identified in the field form the basis for tagging 3Ai mapped polygons for each pilot area as shown in Maps 1 to 3.



Map 1: 3Ai mapped polygons – Royal Camp and Carwong state forests



Map 2: **3Ai mapped polygons – Maria River State Forest**



Map 3: 3Ai mapped polygons – Clouds Creek State Forest (part of)

5.2.2 Koala class assignment to plant community type (PCT)

A core objective of this project was to produce management scale koala habitat mapping (1:5000) for the four pilot areas. During the process of mapping PCT's, it was quickly acknowledged that PCT descriptions varied significantly in terms of its presentation in the field, a fact that is highly amplified within a state forest context.

As an example, the PCT 2171, Tallowwood – Small-fruited Grey Gum – Forest Oak dry open forest, South Eastern Queensland Bioregion and NSW North Coast Bioregion, experiences significant variation in the Maria River study area. Of the 664 hectares mapped, the clear majority (484 hectares) are recorded with a variant (Appendix D). The vast majority of the variants recorded for this PCT are non-feed tree species. Fidel derived koala class for PCT 2171 is nominally a class 1 habitat PCT, only 212 of the 664 hectares are mapped as such. As this degree of variation has been identified it became clear that the assignment of a single koala class across a PCT would result in significant inaccuracy, albeit dependent on the PCT in question as in Table 13 below.

Some PCTs are less variable and therefore are more confidently defined into a koala class, such as flooded gum, blue gum, swamp mahogany dominant types. The degree of survey and field knowledge held by 3Ai was determined to be of higher accuracy than the Fidel derived koala class.

Table 13: Fidel and 3Ai koala class for each plant community type (PCT) in the pilot study area

PCT	Total canopy frequency adjusted cover	Total feed tree frequency adjusted cover	Koala feed tree relative abundance	FIDEL predicted koala class	Median Field assessed koala class	Comments
1939 – Swamp Box – Forest Red Gum – Broad-leaved Paperbark swamp forest of sandy alluvial back swamps in the lower Clarence and Richmond River valleys, South Eastern Queensland Bioregion and NSW North Coast Bioregion	20.7	2.0	10%	Koala Class 3	Koala Class 3	Good match
1943 – Forest Red Gum – Grey Ironbark – Willow Bottlebrush – paperbark shrubby open forest on poorly drained sites in the Port Macquarie area, NSW North Coast Bioregion	10.5	6.5	62%	Koala Class 1	Koala Class 3	Red gum relatively absent at site locality
1948 – River Oak grassy open forest along larger rivers, NSW North Coast Bioregion and South Eastern Queensland Bioregion	35.8	0.8	2%	Koala Class 3	Non habitat	Low cover of red gum in Fidel
2065 – Green-leaved Rose-walnut – Sassafras – Black Booyong – Yellow Carabeen tall closed forest on sediments and meta-sediments of near coastal hills and escarpments, South Eastern Queensland Bioregion and NSW North Coast Bioregion	27.7	0.0	0%	Non habitat	Koala Class 3	RF– non habitat. OK result as 3Ai identified min. KFT
2066 – Black Booyong – Giant Stinging Tree subtropical rainforest of hinterland ranges of the NSW far North Coast, South Eastern Queensland Bioregion and NSW North Coast Bioregion	83.4	0.0	0%	Non habitat	Koala Class 3	RF – map single polygon only. Not supported by analysis sites
2084 – Brush Box – Grey Myrtle – Water Gum dry rainforests of poorer soils of gorges and river valleys, NSW North Coast Bioregion and South Eastern Queensland Bioregion	26.8	0.0	0%	Non habitat	Non habitat	Good match

PCT	Total canopy frequency adjusted cover	Total feed tree frequency adjusted cover	Koala feed tree relative abundance	FIDEL predicted koala class	Median Field assessed koala class	Comments
2085 – Grey Myrtle – Brush Box dry rainforest on meta-sediments and lower nutrient volcanics, NSW North Coast Bioregion and South Eastern Queensland Bioregion	14.3	0.0	0%	Non habitat	Non habitat	Good match
2117 – Scribbly Gum – Bloodwood heathy open forest on poorly drained sandy soils, South Eastern Queensland Bioregion and north-east parts of the NSW North Coast Bioregion	41.7	0.0	0%	Non habitat	Non habitat	Good match
2125 – Cabbage Gum – Broad Leaved Apple open forest of the eastern escarpment, NSW North Coast Bioregion and South Eastern Queensland Bioregion	19.2	12.5	65%	Koala Class 1	Non habitat	Tree strike data for *E. amplifolia* suggests not considered a feed tree
2140 – Tallowwood – New England Blackbutt grassy open forest of plateau areas, New England Tablelands Bioregion and NSW North Coast Bioregion	22.8	1.2	5%	Koala Class 3	Koala Class 2	Based on 1 site. Ignore 3Ai assignment
2156 – Pink Bloodwood – Forest Red Gum – Thick-leaved Mahogany forest at low to mid altitudes between Chaelundi and Toonumbar, NSW North Coast Bioregion and South Eastern Queensland Bioregion	12.5	1.2	10%	Koala Class 3	Koala Class 3	Good match
2157 – Forest Red Gum – Broad-leaved Paperbark – Swamp Box grass/herb open forest in gently undulating areas of the lower Clarence and Richmond River valleys, South Eastern Queensland Bioregion and NSW North Coast Bioregion	16.9	6.8	40%	Koala Class 1	Koala Class 2	3Ai assignment considers low cover of red gum at site
2158 – Grey Ironbark – Broad-leaved Spotted Gum shrub/grass open forest of the Clarence and lower Richmond River valleys, South Eastern Queensland Bioregion and NSW North Coast Bioregion	8.5	0.0	0%	Koala Class 3	Koala Class 3	Good match

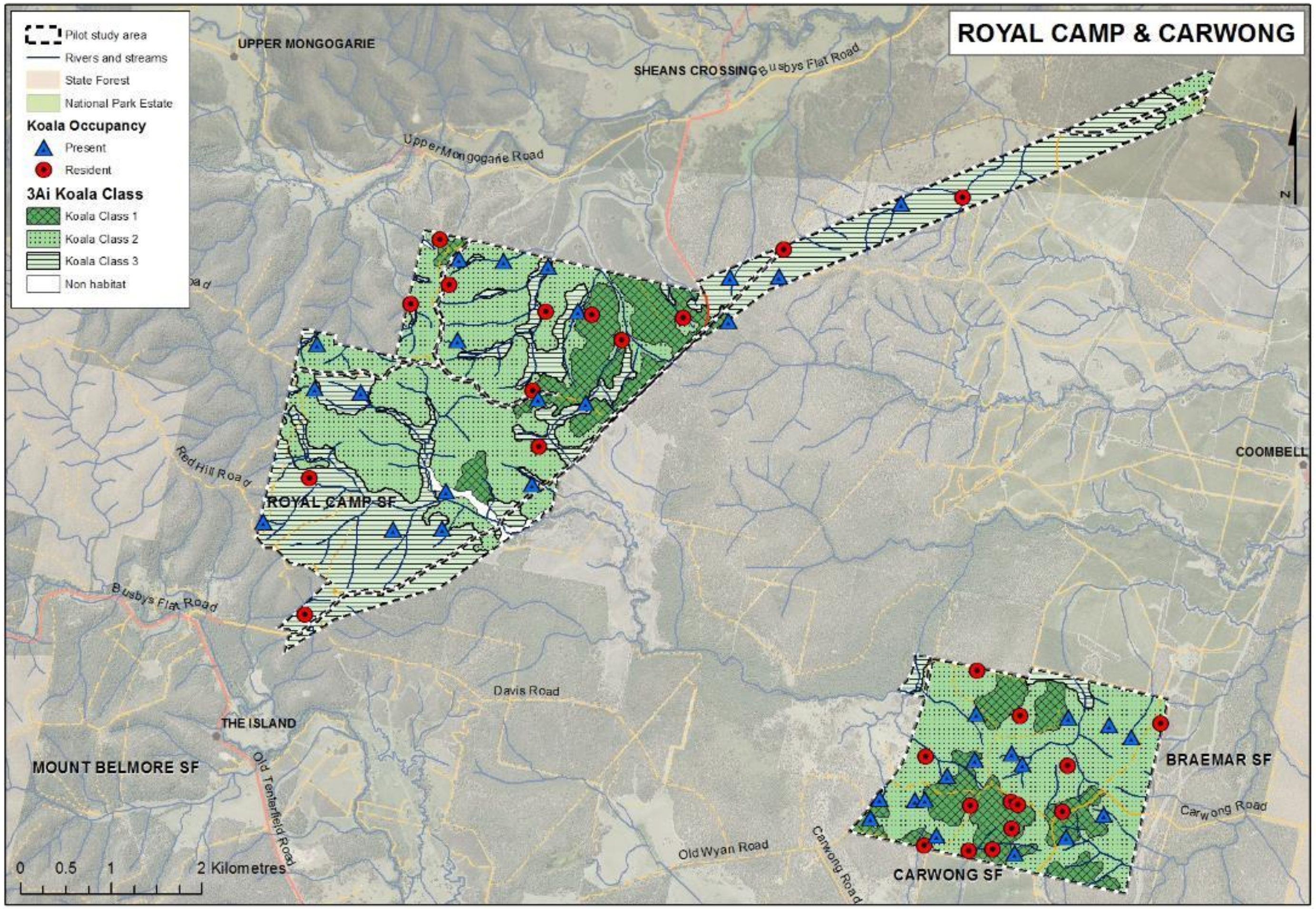
PCT	Total canopy frequency adjusted cover	Total feed tree frequency adjusted cover	Koala feed tree relative abundance	FIDEL predicted koala class	Median Field assessed koala class	Comments
2160 – Blackbutt – Red Mahogany – Bloodwood dry open forest on infertile sandy soils of low coastal rises and hills, NSW North Coast Bioregion, South Eastern QLD Bioregion	23.4	1.2	5%	Koala Class 3	Koala Class 3	Good match
2171 – Tallowwood Small-fruited Grey Gum – Forest Oak dry open forest, South Eastern Queensland Bioregion and NSW North Coast Bioregion	21.3	7.7	36%	Koala Class 1	Koala Class 3	Very even distribution of 3Ai class 1–3 assignment. Large number of variants not KFT
2173 – Spotted Gum Grey Ironbark Thick-leaved Mahogany Small-fruited Grey Gum dry grassy open forest of the Macleay valley hinterland, NSW North Coast Bioregion	70.4	9.9	14%	Koala Class 3	Koala Class 3	Good match
2174 – Tallowwood – Thick-leaved Mahogany – Small-fruited Grey Gum – Grey Ironbark grassy open forest on shallow sedimentary soils, NSW North Coast Bioregion and South Eastern Queensland	47.7	11.8	25%	Koala Class 2	Koala Class 3	Even spread of class assignment 1–3. Large number of variants
2188 – Brush Box – Turpentine – Spotted Gum shrub/grass tall open forest of the escarpment foothills, NSW North Coast Bioregion and South Eastern Queensland Bioregion	41.1	11.3	28%	Koala Class 2	Koala Class 3	3Ai class downgraded on relative absence of KFT
2194 – Turpentine – Blackbutt – Tallowwood dry shrubby open forest on sediments or granites of coastal foothills, NSW North Coast Bioregion and South Eastern Queensland	23.5	9.1	39%	Koala Class 1	Koala Class 3	Even spread of 3Ai class assignment 1–3 as a result of non KFT variance

PCT	Total canopy frequency adjusted cover	Total feed tree frequency adjusted cover	Koala feed tree relative abundance	FIDEL predicted koala class	Median Field assessed koala class	Comments
2226 – Tallowwood – Blackbutt moist shrubby tall open forest of the hinterland ranges of the Mid North Coast, NSW North Coast Bioregion and South Eastern QLD Bioregion	43.9	11.0	25%	Koala Class 2	Koala Class 2	Good match
2227 – Brush Box – Tallowwood – Sydney Blue Gum shrubby wet open forest of coastal hills and escarpment ranges, NSW North Coast Bioregion and the South Eastern Queensland Bioregion	30.4	10.0	33%	Koala Class 1	Koala Class 1	Good match
2228 – Brush Box – Tallowwood Sydney Blue Gum moist shrubby open forest of the hinterland ranges, NSW North Coast Bioregion and the South Eastern Queensland Bioregion	28.3	6.3	22%	Koala Class 2	Koala Class 3	3Ai class downgraded on min. presence of tallowwood
2229 – Turpentine – Brush Box – Flooded Gum – Blackbutt shrubby moist forest of sub-coastal lowlands, NSW North Coast Bioregion and South Eastern Queensland Bioregion	21.6	1.4	7%	Koala Class 3	Koala Class 2	3Ai class upgraded due to grey gum variants
2231 – New England Blackbutt – Tallowwood – Forest Maple moist shrubby tall open forest of the northern escarpment ranges, New England Tablelands Bioregion and NSW North Coast	16.5	1.5	9%	Koala Class 3	Koala Class 2	3Ai class upgraded due to higher tallowwood cover
2239 – New England Blackbutt grassy open forest on well-drained soils on the escarpment, New England Tablelands Bioregion and NSW North Coast Bioregion	18.7	0.0	0%	Non habitat	Koala Class 2	3Ai class upgraded due to higher tallowwood cover
2243 – Grey Box – Forest Red Gum grassy open forest on hills of the mid to upper Clarence and Richmond River valleys, South Eastern QLD Bioregion and NSW North Coast Bioregion	30.0	17.0	57%	Koala Class 1	Koala Class 1	Good match

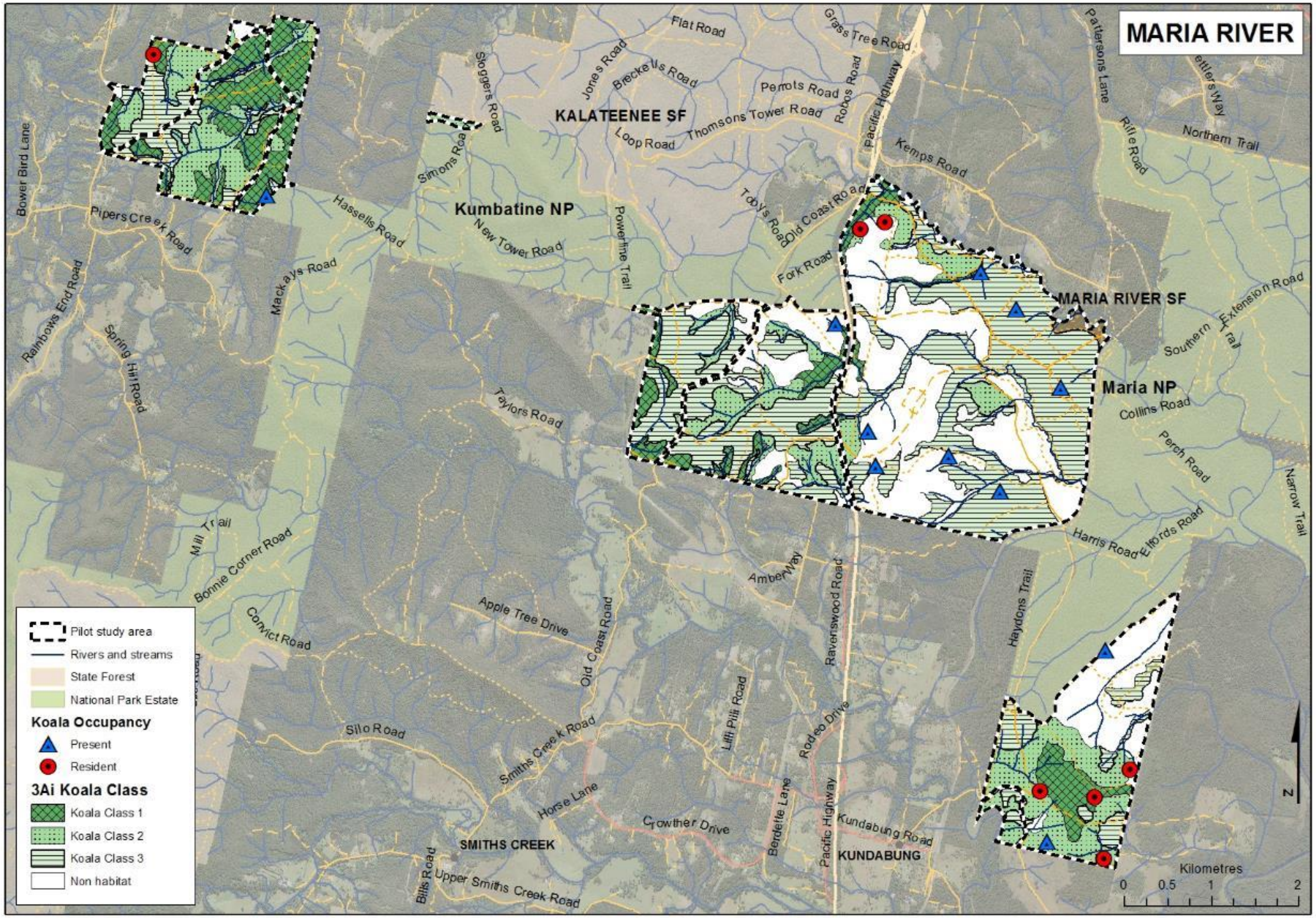
PCT	Total canopy frequency adjusted cover	Total feed tree frequency adjusted cover	Koala feed tree relative abundance	FIDEL predicted koala class	Median Field assessed koala class	Comments
2248 – Pink Bloodwood – Red Mahogany – Swamp Box shrub/grass open forest at low altitudes, South Eastern QLD Bioregion and northern NSW North Coast Bioregion	42.7	0.0	0%	Non habitat	Non habitat	Good match

3Ai mapped koala class for each pilot Area

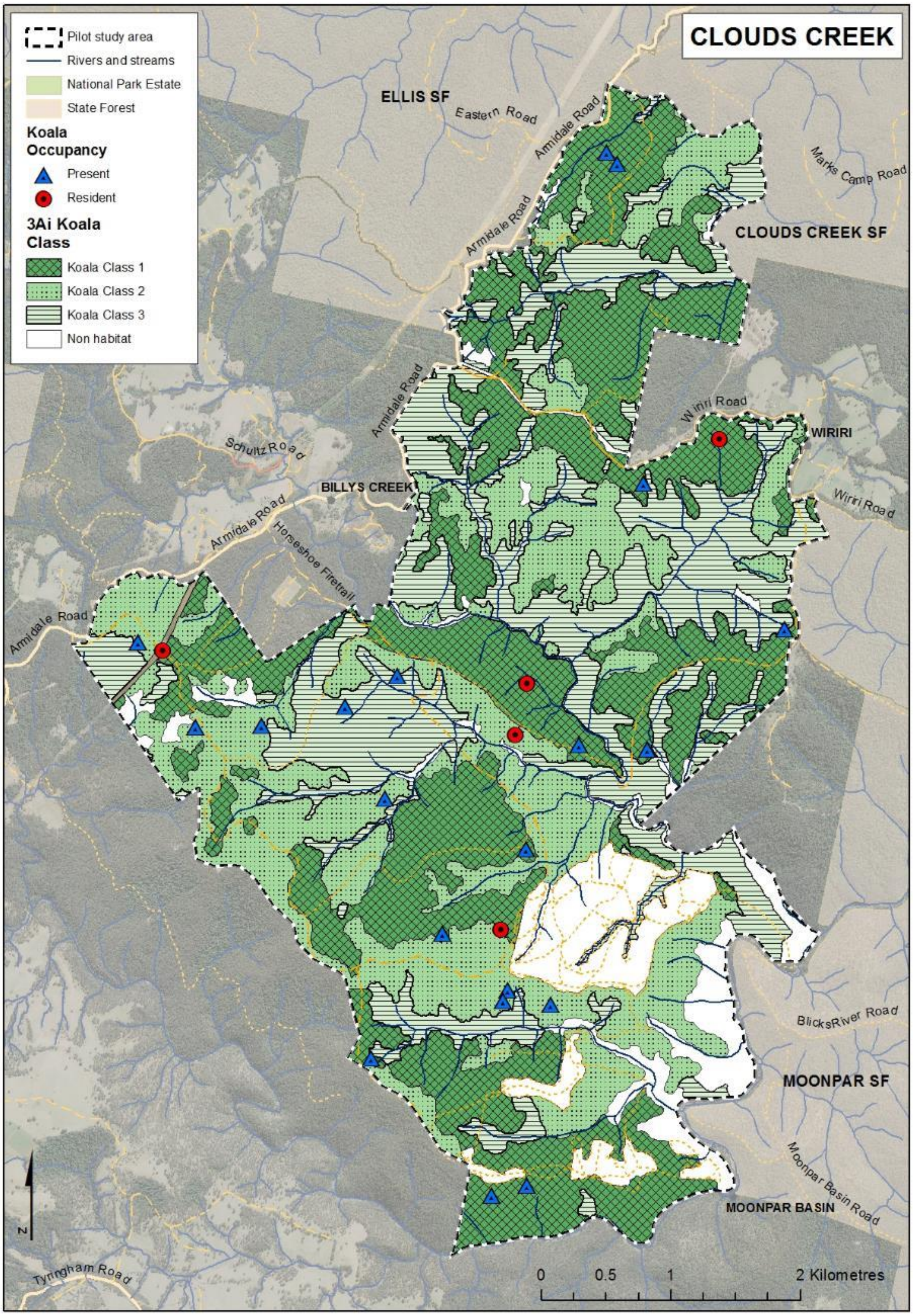
The following map sequence illustrates the collated koala class tagging of mapped PCT by 3Ai. SAT activity is marked to spatially indicate current koala activity within the limitations of the project constraints and survey technique.



Map 4: Activity by 3Ai koala class – Royal Camp and Carwong state forests



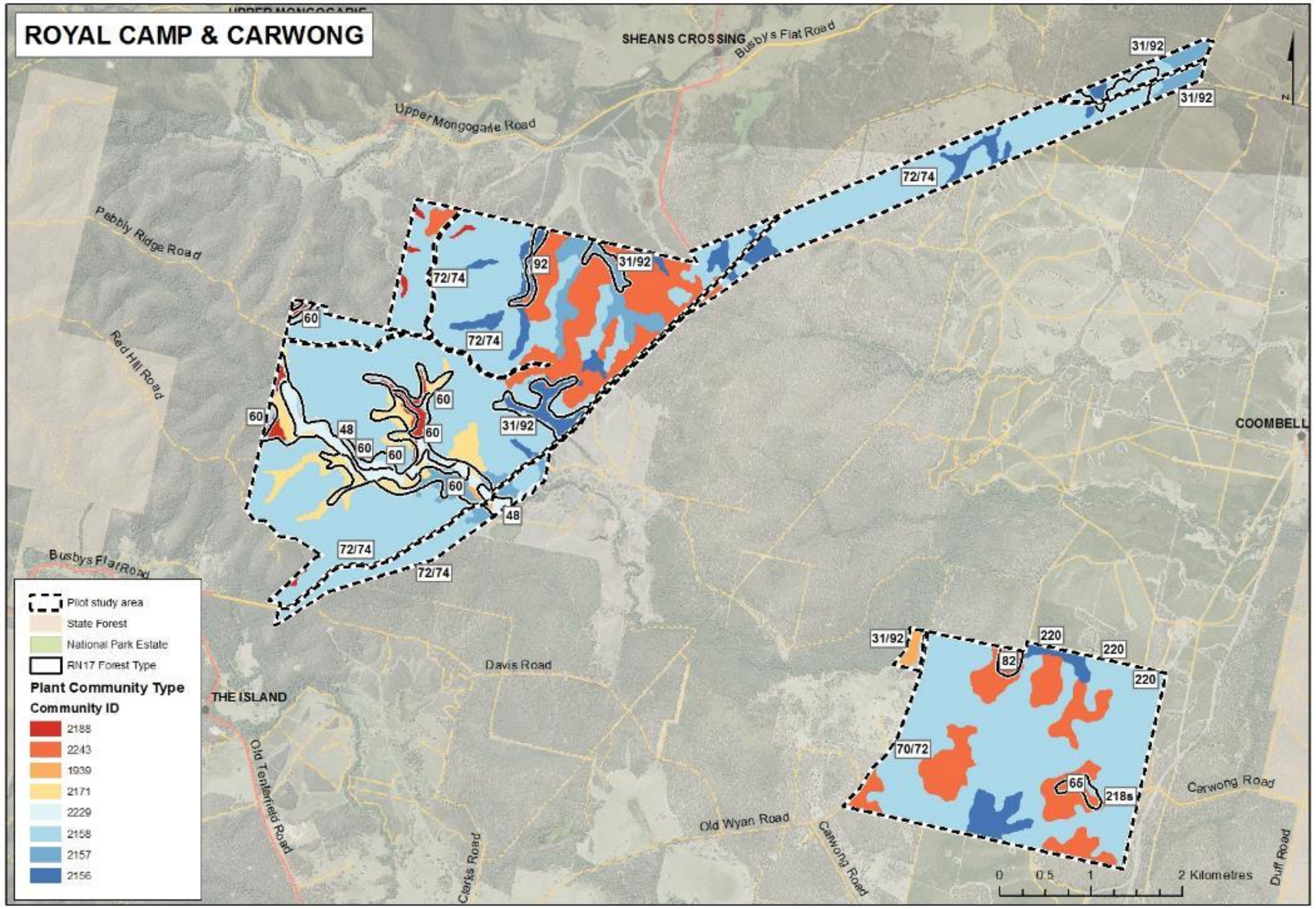
Map 5: Activity by 3Ai koala class – Maria River State Forest



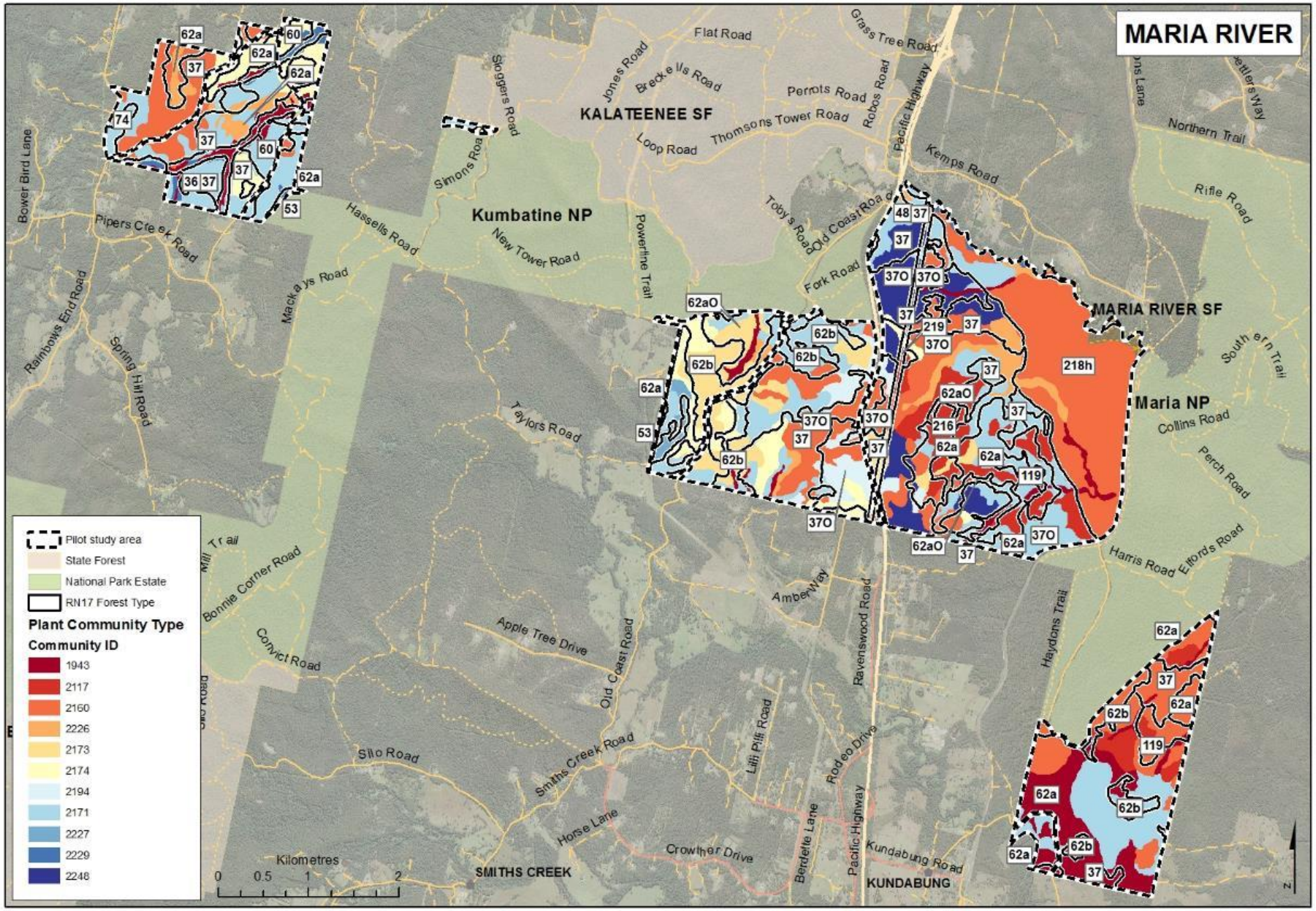
Map 6: Activity by 3Ai koala class – Clouds Creek State Forest

RN17 koala class mapping

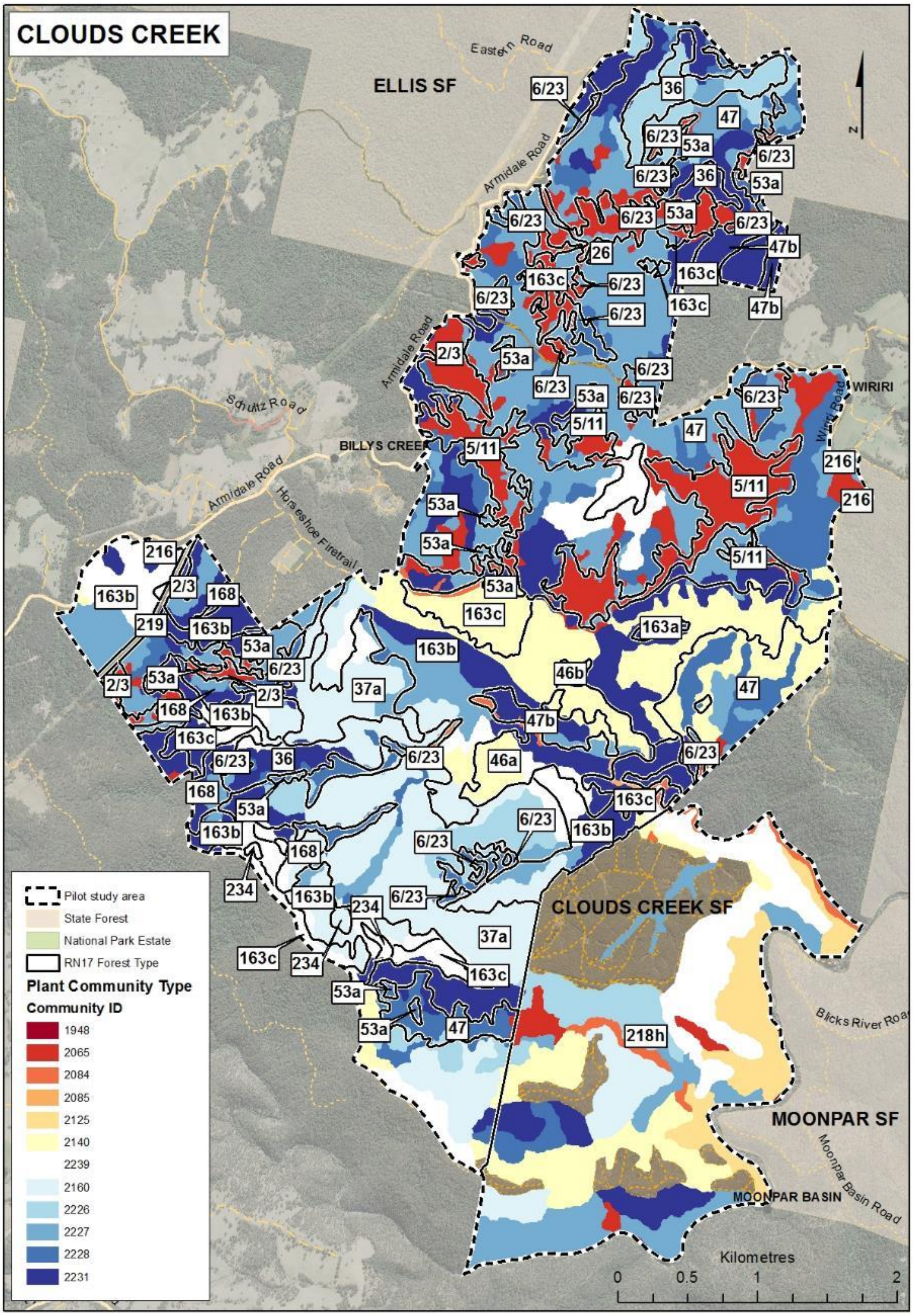
Taking the categories from the reassigned RN17 likely habitat class of high/moderate/low and unsuitable (Appendix E), koala class was derived from RN17 mapping, as denoted by the black line work on the following maps. The variation in vegetation community diversity between 3Ai and RN17 can also be seen.



Map 7: **Royal Camp and Carwong state forests indicating PCT and RN17 (black lines and codes) vegetation polygons**

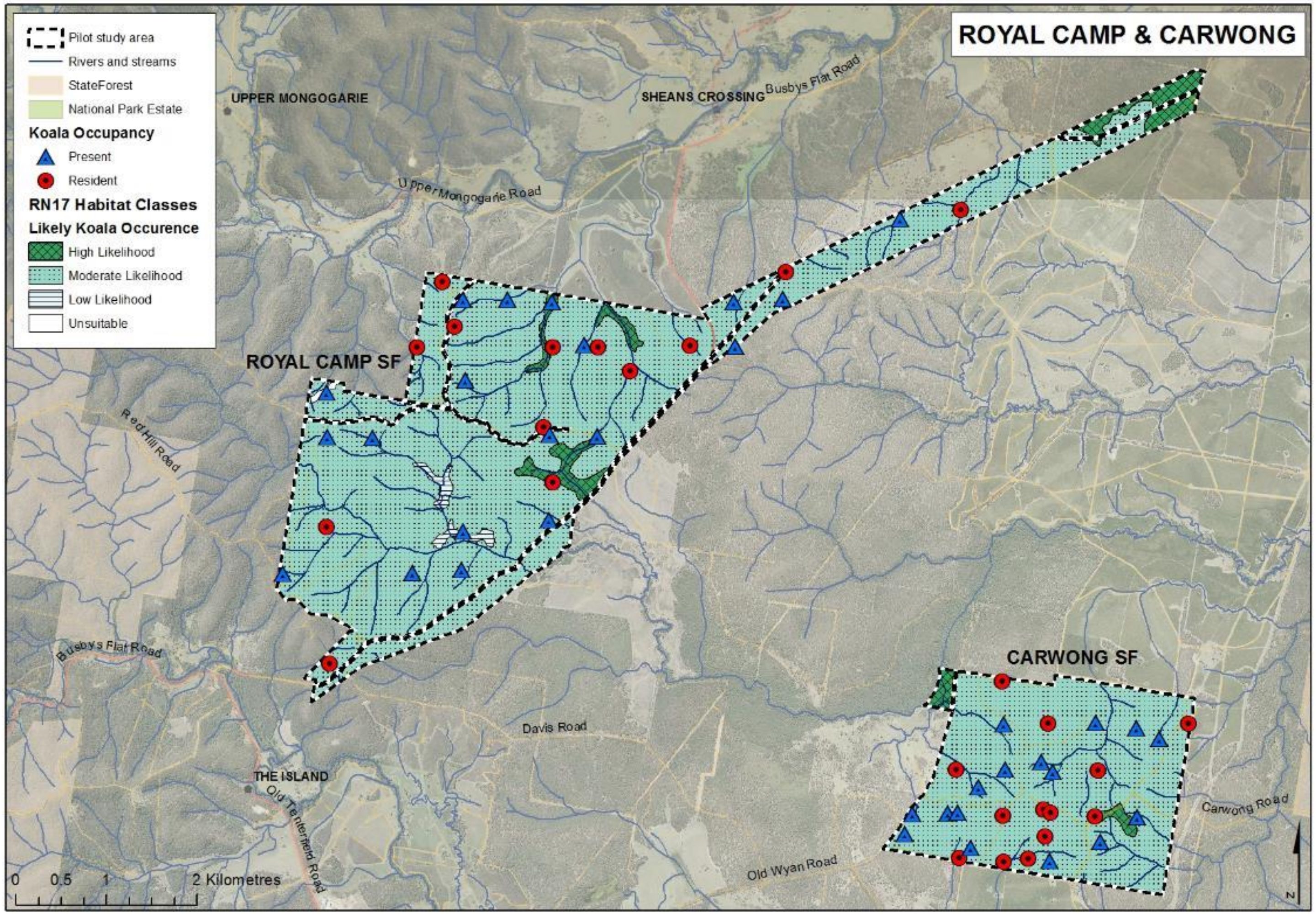


Map 8: **Maria River State Forest indicating PCT and RN17 (black lines and codes) vegetation polygons**

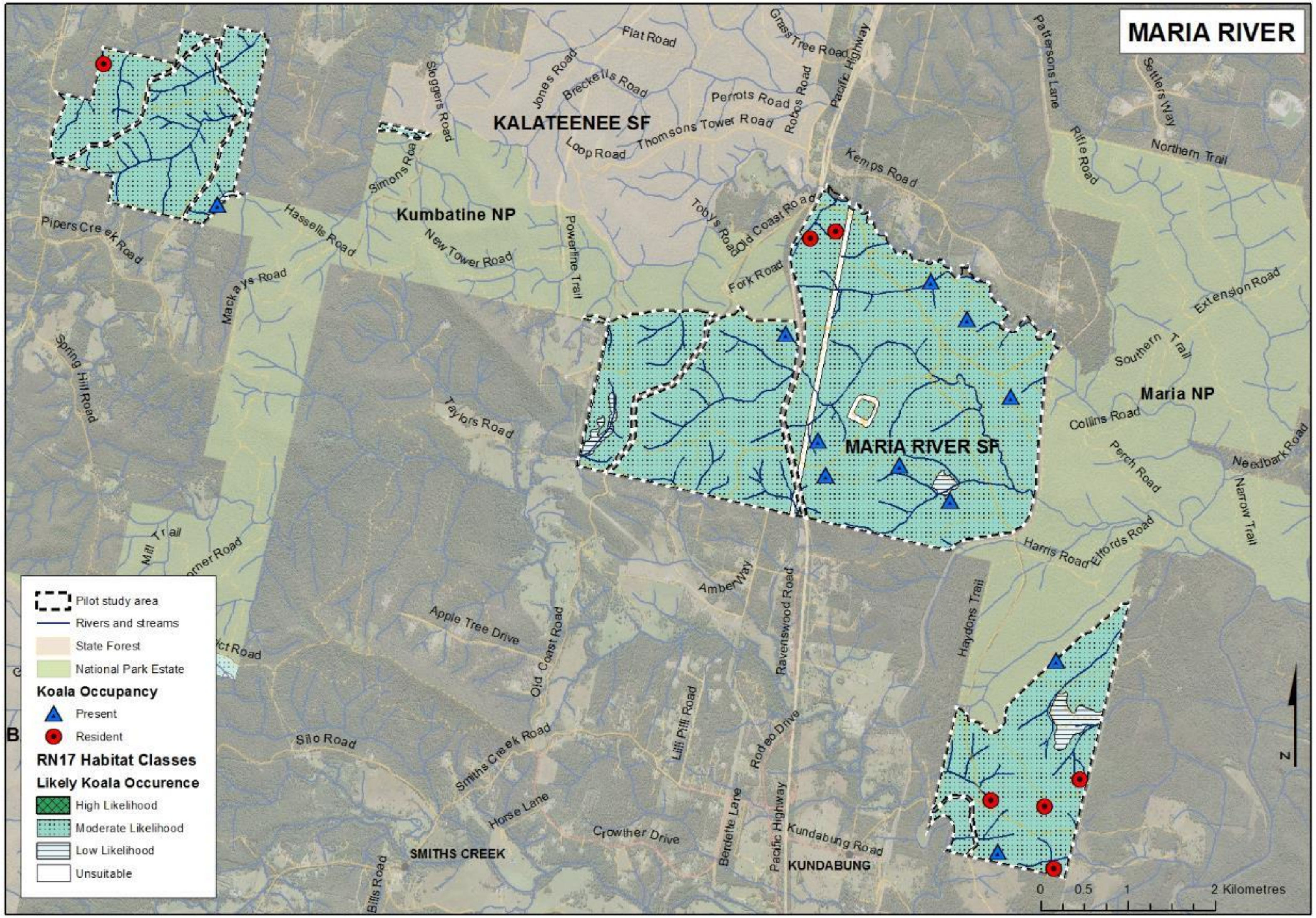


Map 9: Clouds Creek State Forest indicating PCT and RN17 (black lines and codes) vegetation polygons

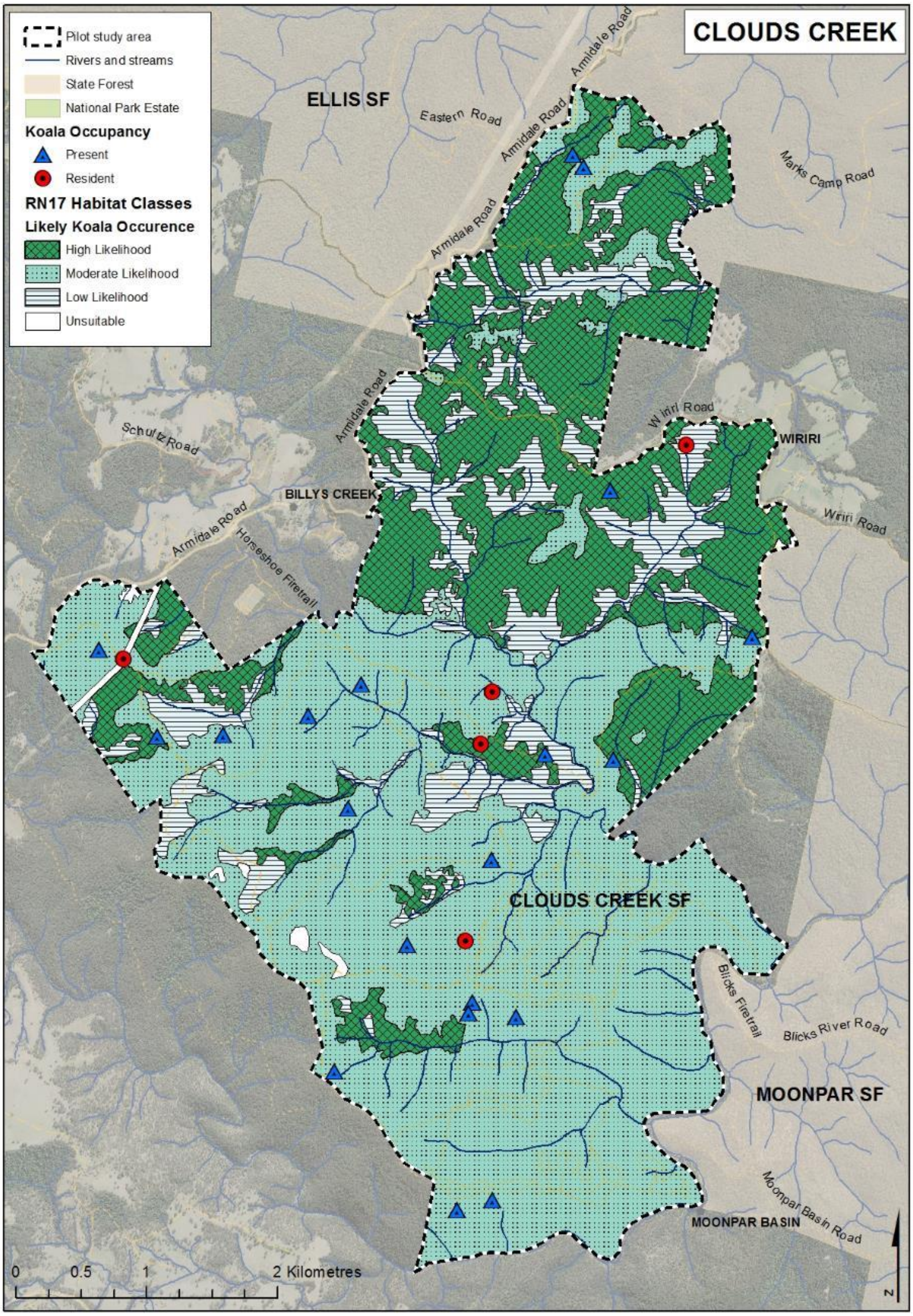
Using the reassigned RN17 types to indicate 'likely koala occurrence' within RN17 types, the following RN17 by SAT activity maps can be compared with the 3Ai koala class maps (Maps 4 to 6).



Map 10: Activity by RN17 class – Royal Camp and Carwong state forests



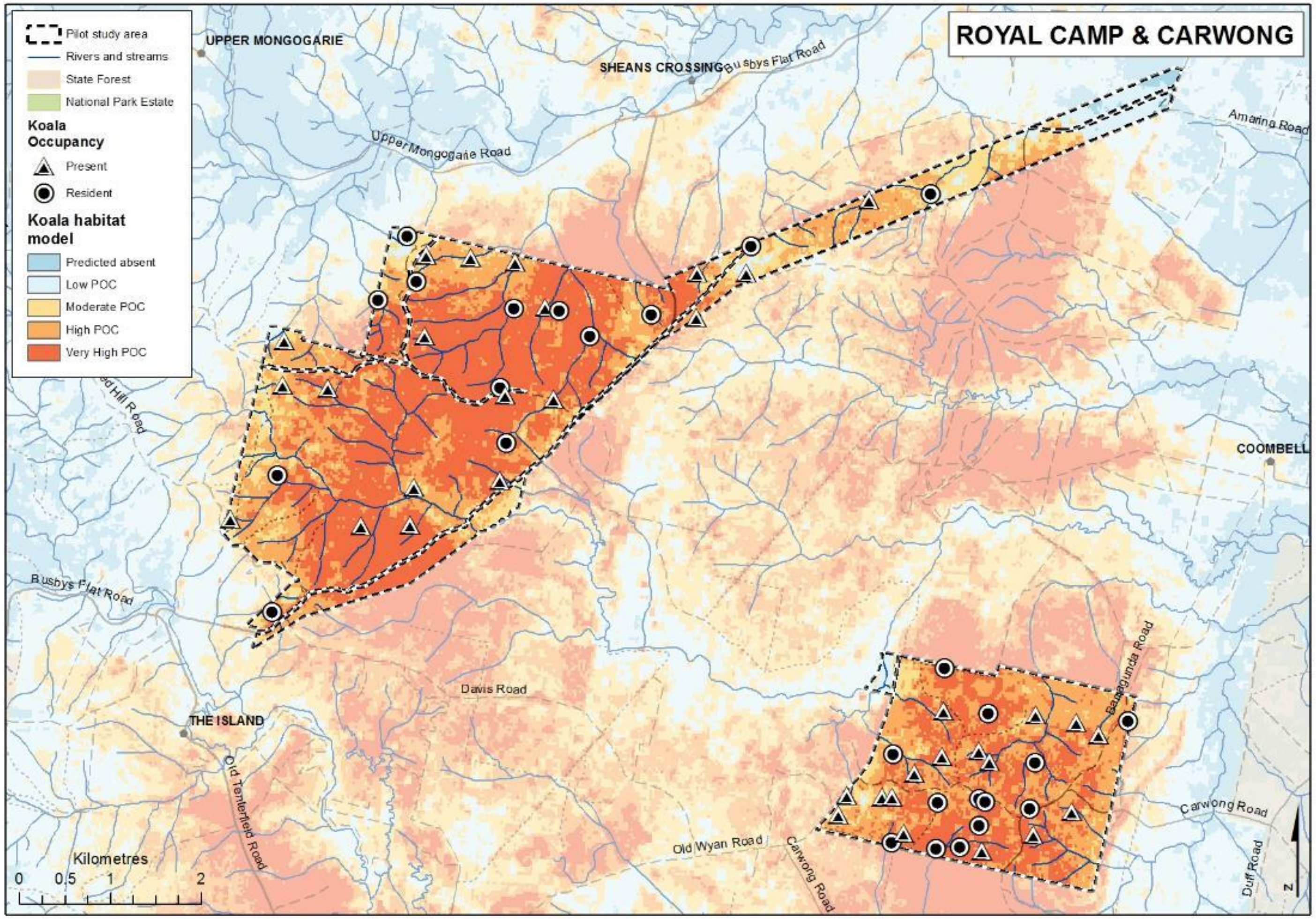
Map 11: Activity by RN17 class – Maria River State Forest



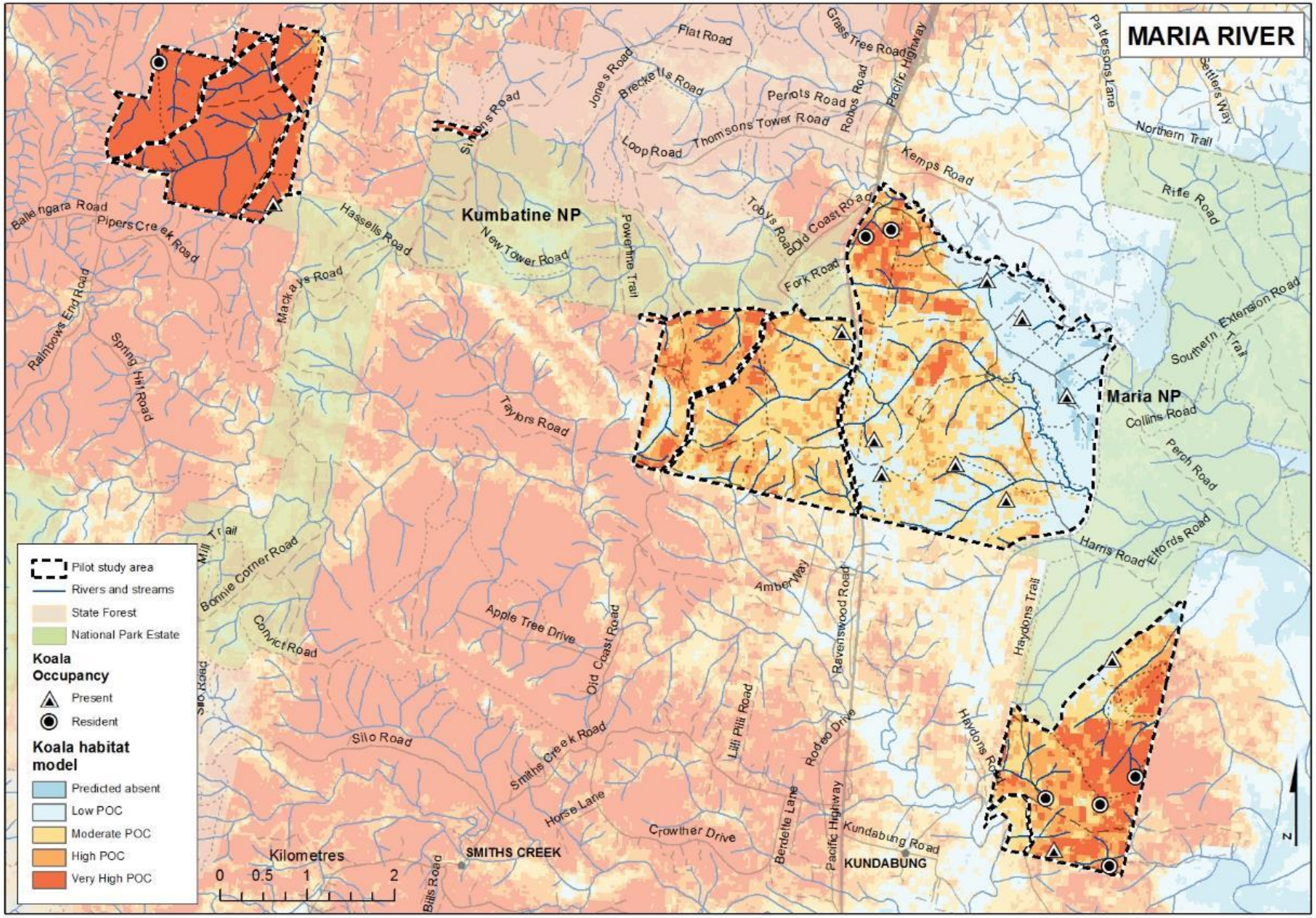
Map 12: Activity by RN17 class – Clouds Creek State Forest

5.2.3 Predictive Modelled Habitat

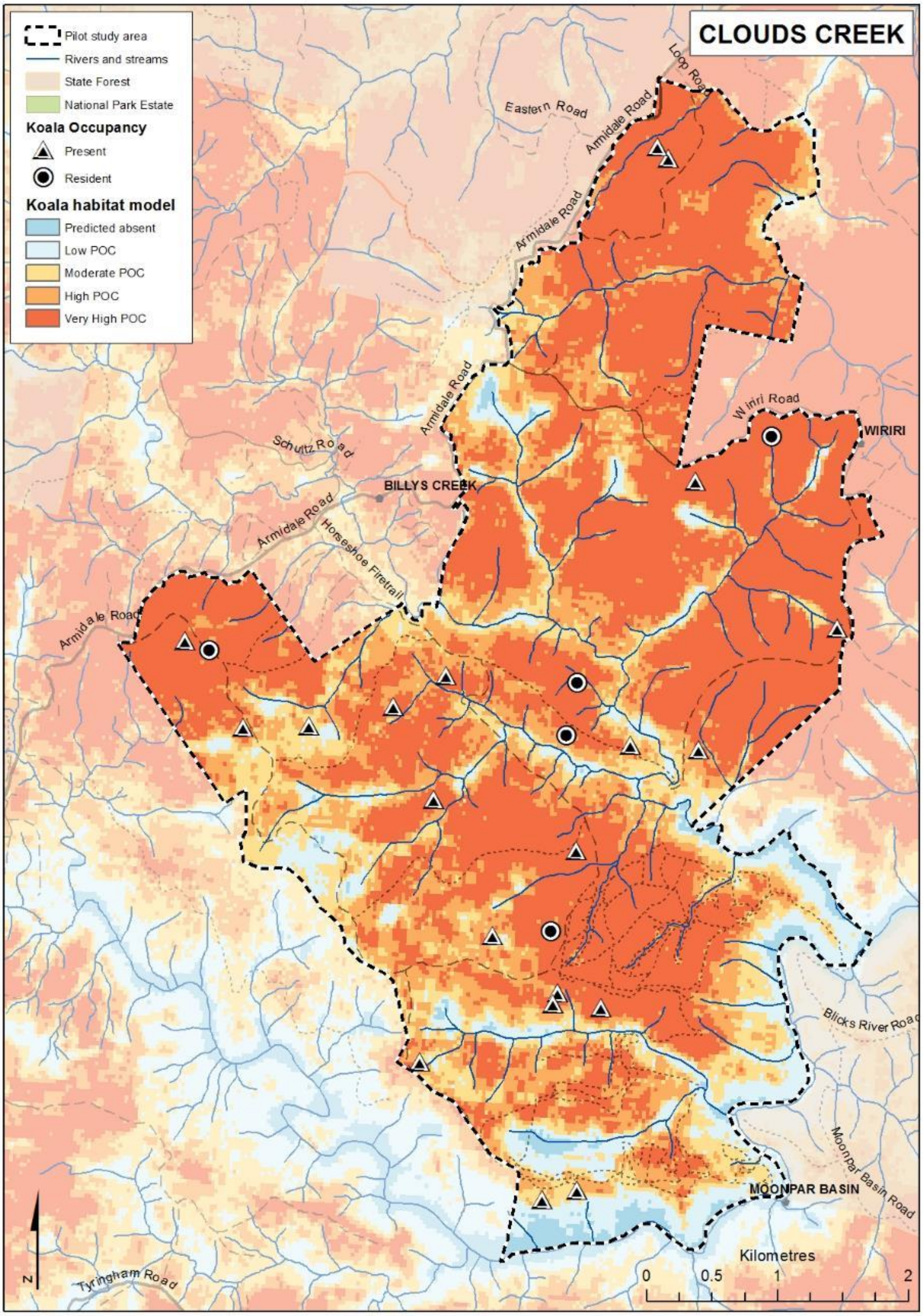
Rescaling the model outputs to an unsuitable and low suitable threshold of <0.65 provided additional areas of low suitability habitat to base new correlation assessments on, as proposed by the expert panel. These map outputs can be viewed below against SAT activity scores.



Map 13: Activity by koala habitat model – Royal Camp (east) and Carwong state forests



Map 14: Activity by koala habitat model – Maria River State Forest



Map 15: Activity by koala habitat model – Clouds Creek State Forest (part)

5.2.4 Comparison of habitat mapping

Part of the objective of comparing mapping systems for koala habitat in this pilot study was to examine not only the distribution of koala habitat, but the overall extent of habitat classes in relative terms. The three mapping systems compared across all pilot areas included:

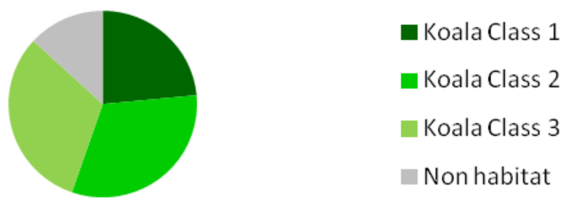
- 3Ai koala class mapping
- RN17 reassigned likely koala habitat class
- Predictive habitat model (POC).

Several statistical trends between mapping techniques are noteworthy:

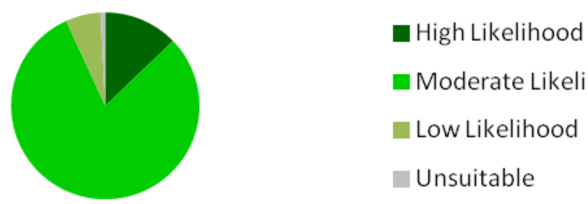
- For the pilot areas, many of the broad ranging types have known feed trees as associate canopy species and this has resulted in a large proportion of the area being categorised as ‘moderate likelihood’ habitat.
- The predictive model, of the three scenarios, has the highest proportion of ‘very high POC’ and ‘high POC’. Relative to other mapping scenarios, the model is top heavy, with 70% of habitat in all pilot areas combined belonging to ‘very high POC’ or ‘high POC’. This contrasts with RN17 mapping, which places an overall proportion of only 13% of habitat into ‘high likelihood’.
- The 3Ai assignment scenario is the most balanced of the three scenarios, with the most abundant overall class being koala class 2 with 32% overall.
- The predictive habitat model scenario is the only scenario which is based on a continuous probability distribution with class boundaries which are able to be modified subject to review.

Overall statistics for the pilot study

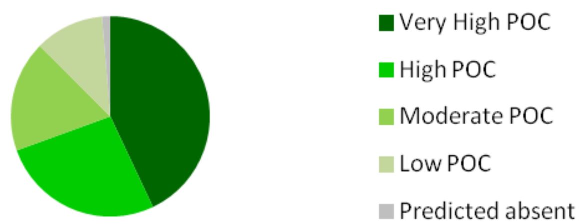
3Ai-PCT	Hectares	% Area
Koala class 1	1,561	23%
Koala class 2	2,120	32%
Koala class 3	2,092	31%
Non habitat	878	13%
Total	6,651	



RN17	Hectares	% Area
High likely	851	13%
Moderate likely	5,360	80%
Low likely	400	6%
Unsuitable	55	1%
Total	6,666	



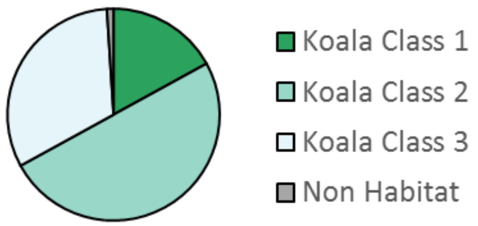
Model	Hectares	% Area
Very high POC	2,864	43%
High POC	1,769	27%
Moderate POC	1,197	18%
Low POC	747	11%
Predicted absent	90	1%
Total	6,667	



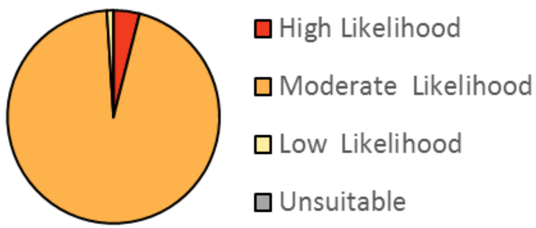
Pilot areas koala class breakdown

Royal Camp and Carwong State Forests

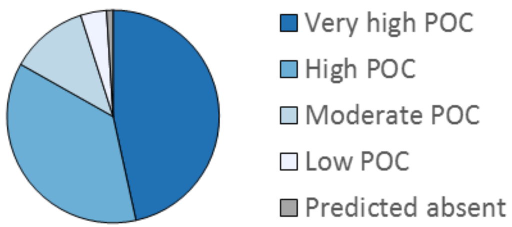
3Ai-PCT	Hectares	% Area
Koala class 1	338	17%
Koala class 2	1,017	50%
Koala class 3	660	32%
Non habitat	16	1%
Total	2,031	



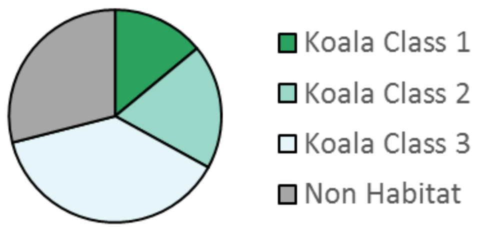
RN17	Hectares	% Area
High Likelihood	89	4%
Moderate Likelihood	1,923	95%
Low Likelihood	15	1%
Unsuitable	3	0%
Total	2,030	

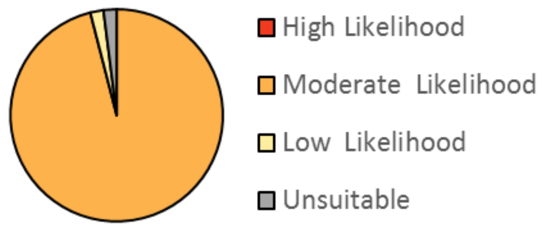


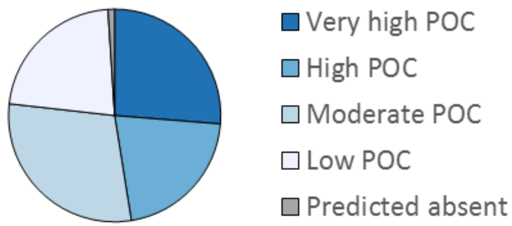
Model	Hectares	% Area
Very high POC	955	47%
High POC	752	37%
Moderate POC	242	12%
Low POC	72	4%
Predicted absent	10	1%
Total	2,031	



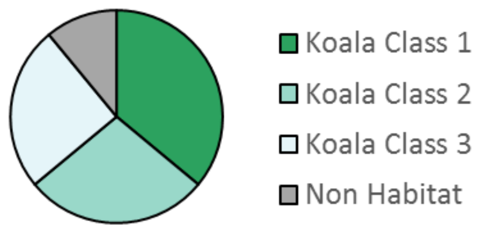
Maria River State Forest		
3Ai-PCT	**Hectares**	**% Area**
Koala class 1	296	14%
Koala class 2	398	19%
Koala class 3	782	38%
Non habitat	593	29%
Total	2,069	
RN17	**Hectares**	**% Area**
High Likelihood	0	0%
Moderate Likelihood	1,994	96%
Low Likelihood	36	2%
Unsuitable (and unmapped)	38	2%
Total	2,068	
Model	**Hectares**	**% Area**
Very high POC	544	26%
High POC	441	21%
Moderate POC	605	29%
Low POC	454	22%
Predicted absent	26	1%
Total	2,069	

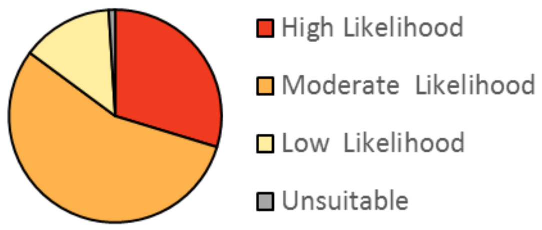


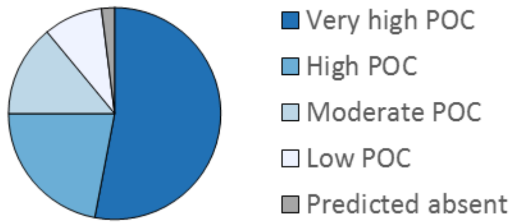




Clouds Creek State Forest		
3Ai-PCT	**Hectares**	**% Area**
Koala class 1	931	36%
Koala class 2	708	28%
Koala class 3	654	25%
Non habitat	273	11%
Total	2,566	
RN17	**Hectares**	**% Area**
High Likelihood	762	30%
Moderate Likelihood	1,442	56%
Low Likelihood	349	14%
Unsuitable	14	1%
Total	2,567	
Model	**Hectares**	**% Area**
Very high POC	1,365	53%
High POC	576	22%
Moderate POC	351	14%
Low POC	221	9%
Predicted absent	54	2%
Total	2,566	







5.2.5 Correspondence of 3Ai mapped koala habitat with modelled probability of occurrence (POC)

As a further validation of the efficacy of the koala habitat model, the modelled categories were overlain with the 3Ai mapped habitat classes and the coincidence of these classes was measured. Table 14 compares the hectares of modelled and mapped habitat classes.

As expected, both mapped and modelled habitat are skewed toward the higher classes, with the non-habitat and predicted absent classes accounting for the least area in the datasets. A notable trend at the higher end of the scale is the slight skewing of habitat away from koala class 1 (in favour of koala class 2) and this is considered a real reflection of habitat quality represented in the landscape and reported in Koala Plans of Management, where minimal coverage of 'primary' habitat is represented. This trend is in contrast to the model which predicts significantly more area of very high POC than any other class.

Table 14: Co-occurrence (by area in hectares) of 3Ai koala class and koala habitat model classes

		Koala habitat model – probability of occurrence					
		Predicted absent	**Low POC**	**Moderate POC**	**High POC**	**Very high POC**	**Total (ha)**
3Ai CLASS	Non habitat	16.9	202.1	282.2	176.8	200.5	878.5
	Koala class 3	40.6	380.1	453.7	529.1	684.6	2,088.1
	Koala class 2	8.4	80.8	298.8	698.6	1,033.3	2,119.9
	Koala class 1	21.1	75.9	161.6	362.6	940.6	1,561.8
		87.0	738.9	1,196.3	1,767.1	2,859.0	

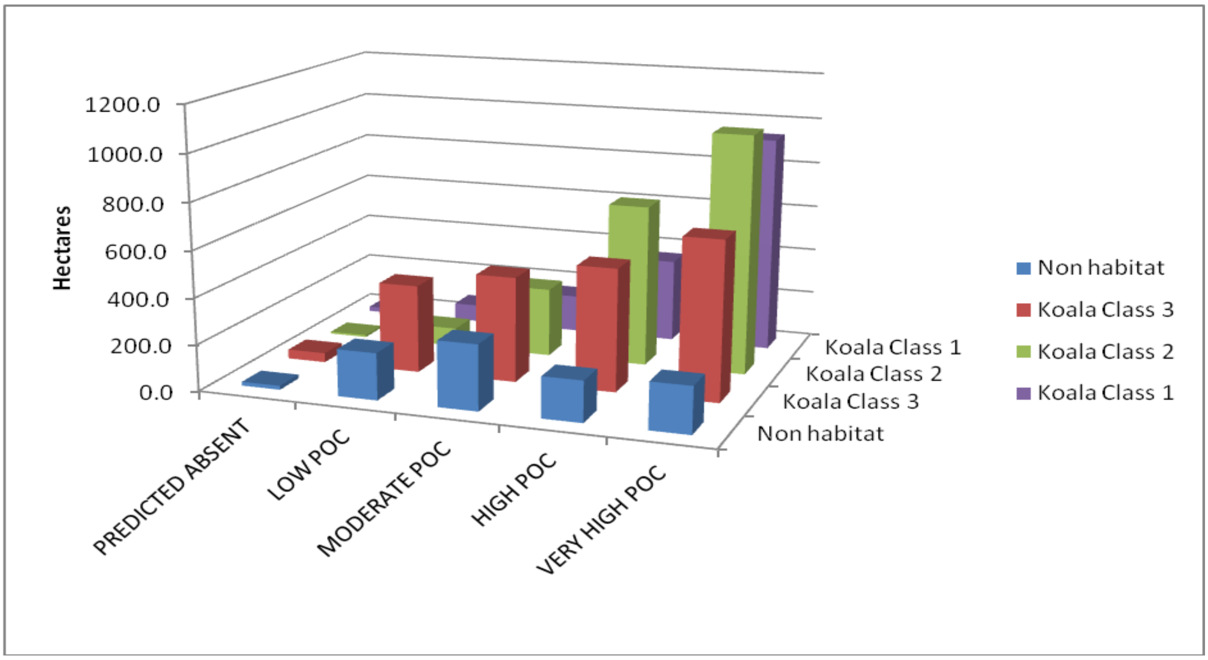


Figure 2: Co-occurrence by area (hectares) of 3Ai koala class and koala habitat model classes

5.3 Koala occupancy

5.3.1 Records analysis

Site analysis

Summary

- Spot assessment technique survey results consistently identified large areas of currently unoccupied habitat across all pilot areas, which is typical of either a low density population or sink habitats impacted by disturbance events.
- Koala activity is largely within class 1 and 2 habitat which aligns with SEPP 44 potential habitat comprising >15% koala feed tree presence.
- Clouds Creek was identified as having the least diversity of feed trees of all the pilot areas, with only tallowwood statistically supported. Maria River had the second least diversity of feed trees, with only tallowwood and small-fruited grey gum statistically supported. Carwong and Royal Camp had the highest overall diversity and abundance of feed trees (five in all) and also the highest overall koala activity.
- Analysis of size class data for Carwong, Royal Camp and Clouds Creek indicate that koalas preference for utilisation of feed trees by koalas is towards larger trees (higher diameter at breast height >30 centimetres).
- Koala activity showed a weak positive relationship for both the abundance and diversity of feed trees at the site level.

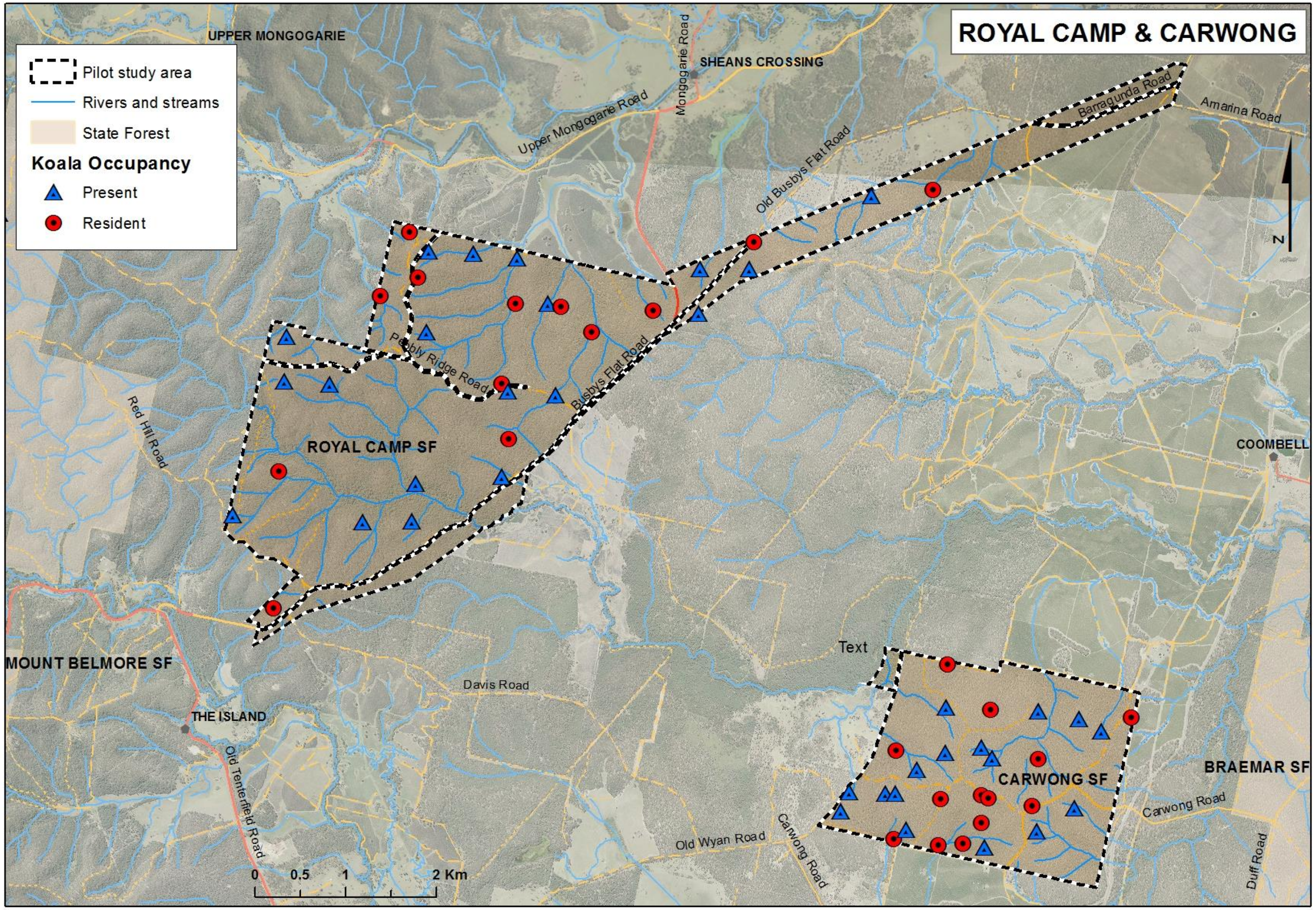
A total of 227 SAT sites (including Royal Camp west) and 70 hectares of spotlighting was undertaken between March and May 2015. Of these, 104 sites were found to be active and 123 koala habitat sites were non active. The majority of activity spread across classes 1 and 2, as shown in Table 15.

Table 15: Number of SAT sites across koala classes – all study areas

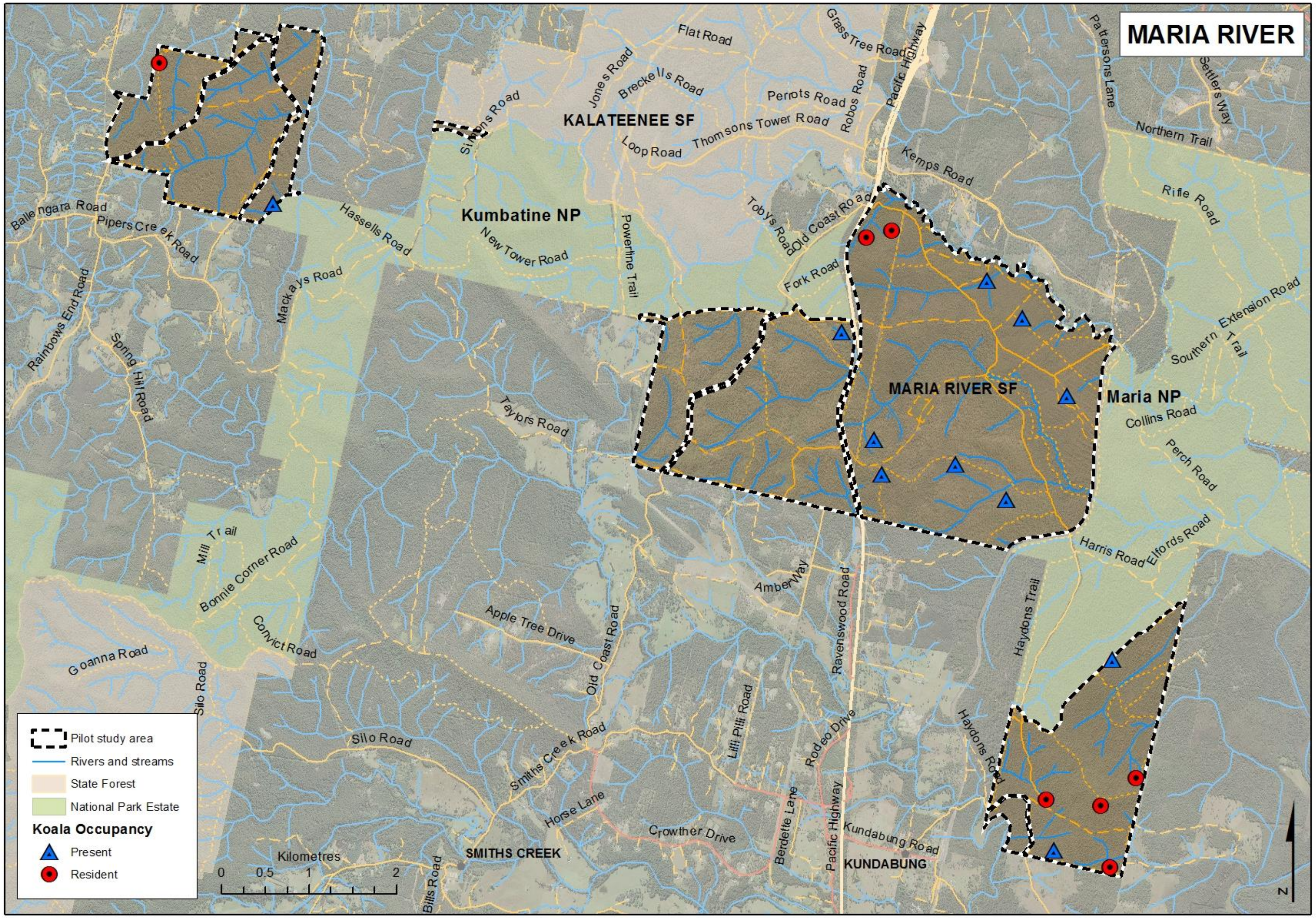
	SAT activity				
API koala class	**High activity**	**Normal activity**	**Low activity**	**Absent**	**Total**
Koala class 1	4	10	24	70	70
Koala class 2	4	13	24	44	85
Koala class 3	1	5	13	41	60
Non habitat		1	5	6	12
Total	9	29	66	123	227

Overall SAT activity by pilot area

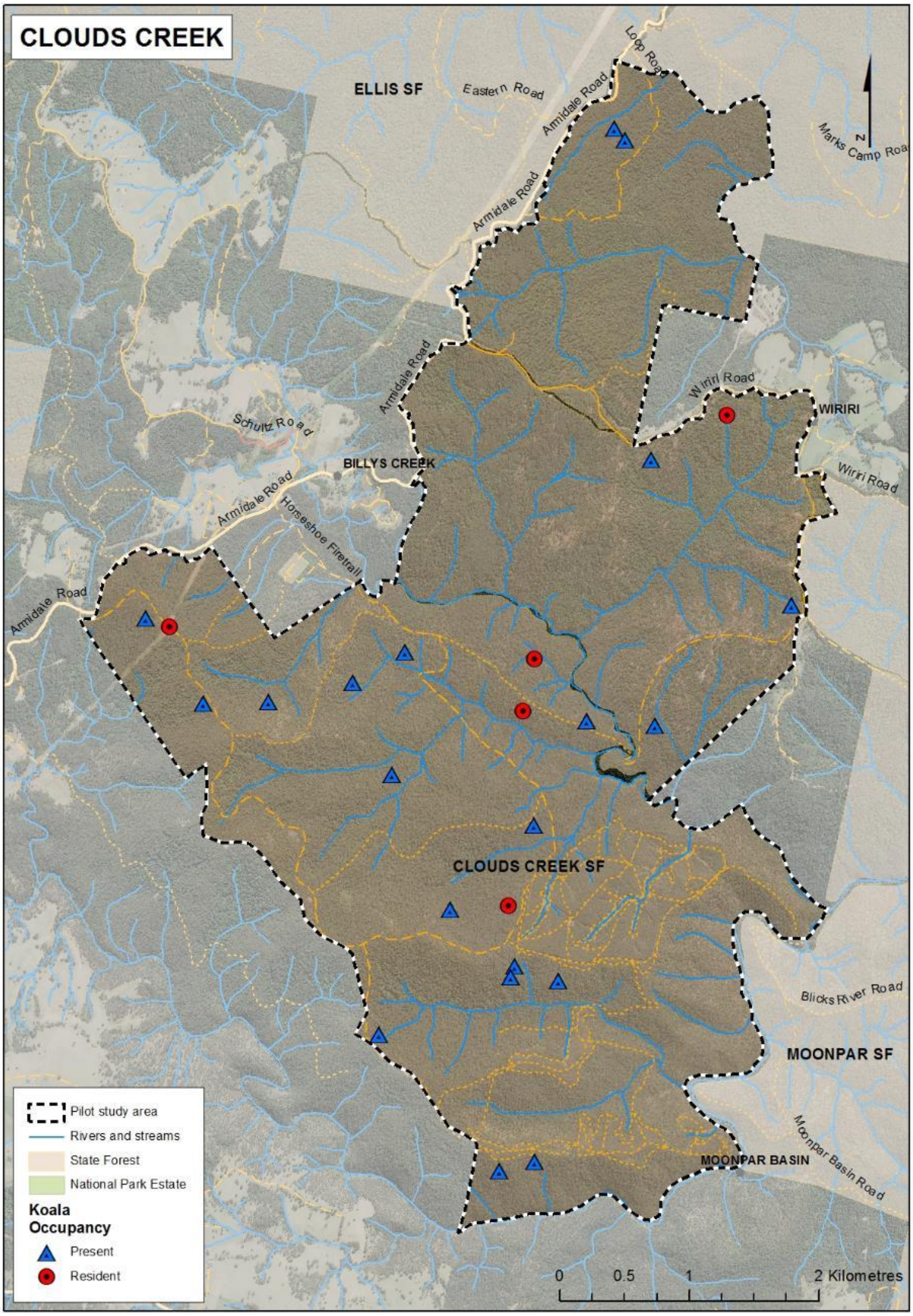
Initially, analysis of data was based on all SAT activity (present and absent sites) as shown in Maps 25 to 27 below. As the original analysis found minimal koala activity correlation with habitat quality, the expert panel proposed using active sites only within two nominal classes of activity, being less than 10% activity to represent potential ‘transient’ animals and categorised as ‘present’, and greater than 10% to represent ‘resident’ animals as shown in maps 25 to 27. This data was the basis for interpolated analysis to determine habitat utilisation and priority koala habitat zones for protection.



Map 25: Royal Camp and Carwong state forests – koala occupancy



Map 26: Maria River State Forest – koala occupancy



Map 27: Clouds Creek State Forest – koala occupancy

Activity data for SAT sites are presented in terms of occupancy (see Table 16). While all the state forest areas show a significant occupancy of koalas, there are a number of trends to note. Clouds Creek State Forest has the lowest overall occupancy with only four resident sites and 21 sites where koalas were present, giving an overall occupancy of just 27%. The western block of Royal Camp State Forest was surveyed but eventually excluded from the pilot study. The results are included here for completeness. The highest resident rates were recorded in the eastern block of Royal Camp and Carwong state forests.

Table 16: Occupancy rates by state forest area

State Forest	Present	Present %	Resident number	Resident %	Currently Unoccupied	Currently Unoccupied %	Total
Royal Camp	21	35%	11	18%	28	47%	60
Carwong	22	55%	7	18%	11	28%	40
Maria River	13	36%	5	14%	18	50%	36
Clouds Creek	21	23%	4	4%	66	72%	91
Total	77	34%	27	11%	123	54%	227

Tree utilisation

Activity and species preferences by state forest area

SAT tree data was combined for grid and model stratified sites, summarised by pilot area and activity data extracted on a species basis. These statistics give an insight into species being preferenced for utilisation at a site level, the degree of use independent of determinant koala feed trees, and the overall proportion of trees being utilised as habitat (infrequent feed trees and shelter trees) as part of the plant community type being utilised.

The main feed tree species in Royal Camp State Forest is small-fruited grey gum. To a lesser extent, grey box and forest red gum are also significant. In the major gully line (Sandy Creek), tallowwood was recorded in an active site but is only present at a low frequency.

The major outlier in the data are the scats found under ‘other sclerophyllous’ trees. These records are mainly *Lophostemon suaveolens* (swamp box) and are associated with overtopping, mature and over mature forest red gum. Spotted gum utilisation in Royal Camp State Forest was widespread, with scats recorded under this species across 16 sites. Scats recorded under spotted gum were always in association with a feed tree.

Table 17: Species activity and preferences – Royal Camp (east) State Forest

Species name	Status	Tree count	Mean activity (site)	SD activity (site)	Mean dbh	SD dbh	Trees with scats	Strike rate
Tallowwood (*E. microcorys*)	Feed	2	13.3	9.4	33.5	23.3	1	50%
Forest red gum (*E. tereticornis*)	Feed	16	12.5	11.4	31.3	13.8	5	31%
Small-fruited grey gum (*E. propinqua*)	Feed	118	12.0	9.3	27.7	13.5	24	20%
Grey box (*E. moluccana*)	Feed	64	8.3	4.8	33.3	13.0	8	13%

Species name	Status	Tree count	Mean activity (site)	SD activity (site)	Mean dbh	SD dbh	Trees with scats	Strike rate
Swamp mahogany (*E. robusta*)	Feed	10	5.7	4.2	22.0	14.3	0	0%
Melaleuca spp.	Habitat	4	26.7	17.4	19.8	4.6	2	50%
Other sclerophyllous	Habitat	17	37.8	8.9	17.9	9.0	8	47%
Mahogany	Habitat	10	6.7	6.1	27.1	12.6	2	20%
Stringy bark	Habitat	60	14.3	11.6	23.3	9.7	8	13%
Ironbark	Habitat	134	9.6	7.6	26.6	17.6	14	10%
Spotted gum	Habitat	420	10.0	8.0	26.5	11.1	31	7%
Bloodwood	Habitat	42	13.7	13.7	26.3	13.6	2	5%
Acacia spp.	Non feed	11	16.7	7.9	11.7	0.9	0	0%
Brush box (Lophostemon confertus)	Non feed	2	6.7	0.0	28.0	7.1	0	0%
Blackbutt (*E. pilularus*)	Non feed	1	3.3	0.0	61.0	0.0	0	0%
Other eucalypt	Non feed	6	6.1	1.4	45.7	24.6	0	0%
Allocasuarina spp.	Non feed	30	6.3	4.9	12.7	2.7	0	0%
Rainforest	Non feed	5	13.3	14.9	23.4	11.5	0	0%
Turpentine (Syncarpia glomulifera)	Non feed	8	6.7	0.0	23.6	12.6	0	0%

The main feed tree species of note in Carwong State Forest are small-fruited grey gum, red gum (mainly slaty red gum – *Eucalyptus glaucina* but recorded as forest red gum) and grey box. The records of tallowwood in the data are unconfirmed and are at low frequency in any case. The diversity of feed tree species is also high, with most active sites containing at least two species of feed tree. The abundance of feed trees at active sites is also high, with about a quarter (8%) of all trees at active sites being feed trees.

As with Royal Camp State Forest, of the non-feed trees being utilised at active sites, spotted gum is the most significant, with 30 scats being found across four sites. In all of these four sites, spotted gum is occurring with grey box or small-fruited grey gum.

Table 18: Species activity and preferences – Carwong State Forest

Species name	Status	Tree count	Mean activity (site)	SD activity (site)	Mean dbh	SD dbh	Trees with scats	Strike rate
Small-fruited grey gum (*E. propinqua*)	Feed	57	18.5	12.6	36.5	20.8	18	32%
Forest red gum (*E. tereticornis/glaucina*)	Feed	34	9.5	4.3	29.9	14.8	8	24%
Tallowwood (*E. microcorys*)	Feed	5	36.7	0.0	17.2	1.3	1	20%
Grey box (*E. moluccana*)	Feed	209	9.5	8.2	30.8	15.6	27	13%
Swamp mahogany (*E. robusta*)	Feed	1	3.3	0.0	19.0	0.0	0	0%
Acacia spp.	Habitat	8	9.2	10.4	16.3	3.2	1	13%
Allocasuarina spp.	Habitat	9	11.5	1.8	16.7	3.2	1	11%
Spotted gum	Habitat	443	8.9	6.7	26.8	14.5	30	7%
Bloodwood	Habitat	30	10.3	8.5	20.8	8.2	1	3%
Ironbark	Habitat	60	10.8	8.4	24.2	12.1	1	2%
Melaleuca spp.	Non feed	3	18.9	7.7	12.3	4.0	0	0%
Mahogany	Non feed	6	12.8	1.4	34.3	23.4	0	0%
Rainforest	Non feed	1	10.0	0.0	16.0	0.0	0	0%
Stringy bark	Non feed	4	3.3	0.0	49.5	21.2	0	0%

Tallowwood and grey gum are both moderately abundant and well utilised in Maria River State Forest. Both of these feed tree species were present at all but two active sites. At the two active sites without feed trees, bloodwood and other eucalypt (not identified) trees were the utilised trees. Brush box use is restricted to one site and is associated with tallowwood and small-fruited grey gum. Blackbutt use occurs on three sites, all of which have tallowwood present.

Table 19: Species activity and preferences – Maria River State Forest

Species name	Status	Tree count	Mean activity (site)	SD activity (site)	Mean dbh	SD dbh	Trees with scats	Strike rate
Tallowwood (*E. microcorys*)	Feed	54	8.3	5.5	32.6	20.3	9	17%
Small-fruited grey gum (*E. propinqua*)	Feed	33	8.5	6.4	28.4	12.3	3	9%
Brush box (Lophostemon confertus)	Habitat	10	20.7	5.6	26.6	9.4	2	20%
Blackbutt (*E. pilularus*)	Habitat	52	6.1	4.4	37.7	16.0	5	10%
Other eucalypt	Habitat	26	4.5	1.6	29.0	13.5	2	8%
Mahogany	Habitat	145	7.4	5.4	28.4	10.7	11	8%
Turpentine (Syncarpia glomulifera)	Habitat	46	8.3	6.6	24.3	10.5	3	7%
Bloodwood	Habitat	65	8.4	5.5	27.5	11.6	4	6%
Ironbark	Habitat	18	12.0	8.6	37.3	15.4	1	6%
Allocasuarina spp.	Habitat	84	9.2	6.2	16.3	5.9	4	5%
Melaleuca spp.	Non feed	4	5.0	1.9	15.8	2.4	0	0%
Stringy bark	Non feed	1	3.3	0.0	26.0	0.0	0	0%
Spotted gum	Non feed	2	3.3	0.0	23.5	9.2	0	0%

In the Clouds Creek pilot area, in the absence of scat dietary analysis, only one recognised feed tree was recorded with scats, being tallowwood. Common associated species such as *Allocasuarina* spp. and rainforest spp. were the next highest in terms of utilisation. The presence of scats under oak and rainforest trees can be explained by association with tallowwood. A review of the active sites in Clouds Creek State Forest revealed that tallowwood was present in all cases.

Table 20: Species activity and preferences – Clouds Creek State Forest

Species name	Status	Tree count	Mean activity (site)	SD activity (site)	Mean dbh	SD dbh	Trees with scats	Strike rate
Tallowwood (*E. microcorys*)	Feed	192	7.2	6.0	39.4	19.8	34	18%
Allocasuarina spp.	Habitat	257	5.8	4.1	26.0	9.9	11	4%
Rainforest	Habitat	38	8.0	4.4	18.9	8.3	1	3%
Sydney blue gum	Habitat	98	6.3	6.1	40.4	20.2	2	2%
New England blackbutt (*E. campanulata*)	Habitat	62	5.9	4.3	48.8	28.1	1	2%
Acacia spp.	Non feed	16	6.3	6.8	21.3	10.2	0	0%
Brush box (Lophostemon confertus)	Non feed	26	7.6	4.5	32.0	12.4	0	0%

Species name	Status	Tree count	Mean activity (site)	SD activity (site)	Mean dbh	SD dbh	Trees with scats	Strike rate
Blackbutt (*E. pilularus*)	Non feed	52	5.9	4.5	41.9	31.1	0	0%
Die-hard stringybark (*E. cameronii*)	Non feed	5	3.3	0.0	32.2	13.4	0	0%
Other eucalypt	Non feed	22	3.3	0.0	44.0	17.3	0	0%
Other exotic spp.	Non feed	1	6.7	0.0	27.0	0.0	0	0%
Mahogany	Non feed	4	3.3	0.0	58.0	12.3	0	0%
Stringy bark	Non feed	3	3.3	0.0	29.0	10.8	0	0%
Turpentine (Syncarpia glomulifera)	Non feed	4	5.0	1.9	24.8	11.5	0	0%

Species size class variation with activity

As tree retention is considered a habitat protection measure, it is important to determine which size class of koala feed tree species is preferred. Past studies have identified an association between abundance of feed trees in larger size classes and koala utilisation. For example, Phillips (2013) found preferencing for grey gum species >30 cm dbh on low fertility soils in compartment 13 of Royal Camp State Forest. Smith (2004) found an association between the number of trees in larger size classes (50–80 centimetres) and abundance of scats in Pine Creek State Forest. With this in mind, key species were targeted for investigation to validate the relationship between utilisation by koalas and size class. Species investigated by pilot area are presented in Table 21.

Table 21: Species investigated for size class versus koala activity association

State forest pilot area	Species
Royal Camp & Carwong state forest areas	Small-fruited grey gum (*E. Propinqua*)
Royal Camp & Carwong state forest areas	Grey box (E. Moluccana)
Maria River State Forest	Tallowwood (*E. Microcorys*)
Maria River State Forest	Small-fruited grey gum (*E. Propinqua*)
Clouds Creek State Forest	Tallowwood (*E. Microcorys*)

Forest red gum (*E. tereticornis*) was excluded from analysis based on the low overall abundance and subsequent small sample size for analysis, despite a known high utilisation by koalas.

The low overall positive scat records in Maria River State Forest made statistically valid analyses difficult in this pilot area. Investigation of size class relationships for both tallowwood and small-fruited grey gum were not pursued on this basis.

Small-fruited grey gum in Royal Camp and Carwong state forests

A total of 166 records of small-fruited grey gum were observed within active SAT sites in Royal Camp State Forest and Carwong State Forest. From a minimum size class of 100 millimetres, the observed stems were pooled into the size classes shown in Table 22.

Table 22: Observed data for pooled size classes – small-fruited grey gum (*E. propinqua*)

Dbh class	Scat	No scat	Total	Strike rate
150 (100–199 mm)	8	40	48	16.7%
225 (200–249 mm)	6	20	26	23.1%
300 (250–349 mm)	6	35	41	14.6%
400 (350–449 mm)	5	11	16	31.3%
500 (450–549 mm)	5	12	17	29.4%
700 (550–1049 mm)	9	9	18	50.0%
Total	39	127	166	23.5%

Strike rate was then plotted against diameter at breast height using this pooled size class data and a linear regression model was calculated (Figure 4). A strong positive correlation co-efficient (R^2=0.827) with a small dataset indicates a strong positive relationship between the size class of this species and usage by koalas.

A test of independence (chi test) was then undertaken to determine if there was a critical size class above which utilisation by koalas becomes more significant. Using all the data, a p value of 0.0525 is resultant, indicating a strong, but not quite statistically significant likelihood of a dependent relationship between size class and activity. A breakdown of this activity into individual size classes reveals that the two largest size classes have the strongest relationship with activity, beyond which the variables become more independent (Table 23).

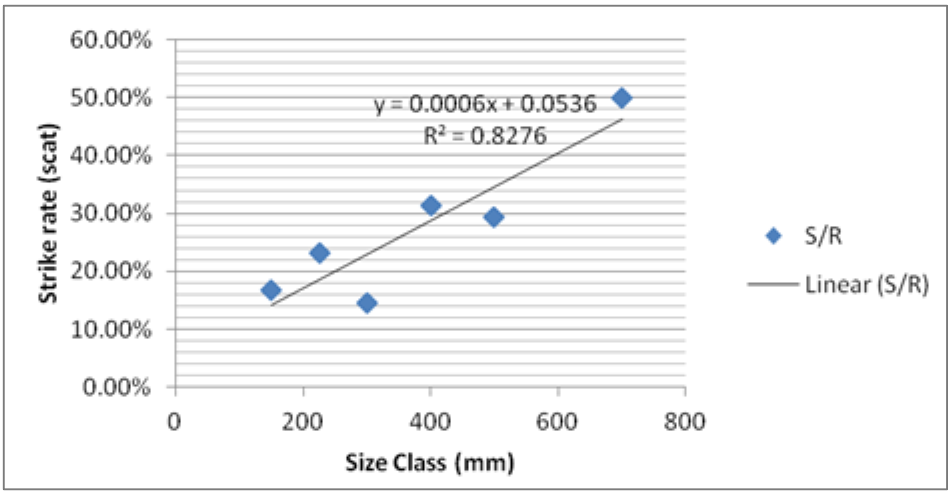


Figure 4: Size class of small-fruited grey gum versus scat strike rate

Table 23: Chi test of independence – size class versus utilisation by koalas

Class	Chi test (bottom up)	Chi test (individual classes)	Chi test (top down)
p 150	0.2645544	0.26455438	0.05257749
p 225	0.2640721	0.95999543	0.04588174
p 300	0.2189508	0.18086128	0.02136464
p 400	0.3113789	0.46431055	0.01923124
p 500	0.4190819	0.56494197	0.00664333
p 700	0.0525775	0.0079899	0.0079899

Grey box in Royal Camp and Carwong state forests

A total of 271 observations of grey box were made in Royal Camp State Forest and Carwong State Forest from active SAT sites. Of those observations, only 34 (12.5%) were positive (with scat). Despite the lower overall strike rates, the data displays a similar strong relationship between dbh and size class, with higher activity in larger size classes.

Table 24: Observed data for pooled size classes – grey box (*E. moluccana*)

DBH class	Scat	No scat	Total	Strike rate
150 (100–199 mm)	5	62	67	7.46%
250 (200–299 mm)	9	65	74	12.16%
350 (300–399 mm)	8	52	60	13.33%
450 (400–499 mm)	6	35	41	14.63%
775 (500–1049 mm)	6	23	29	20.69%
Total	34	237	271	

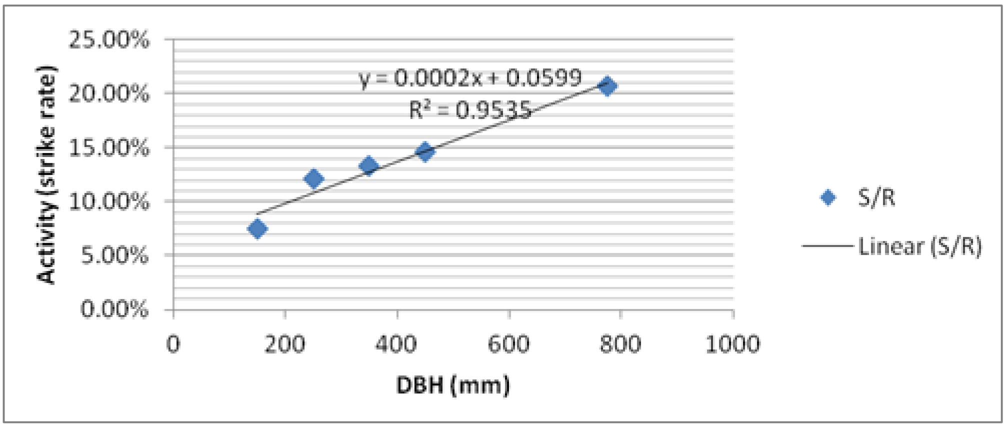


Figure 5: Size class of grey box versus scat strike rate

A linear regression analysis of the strike rate data versus size class shows a strong and statistically significant relationship between the two variables (R^2=0.9535). A chi square test was conducted but the results were unclear, with an overall p value of 0.47 and no clear break point.

Tallowwood in Clouds Creek State Forest

A total of 176 observations of tallowwood (*E. microcorys*) were made at active spot assessment technique sites in the Clouds Creek State Forest pilot area. Of these observations, 34 (19.3%) were positive for koala scats. As with other species investigated, the data demonstrates a strong positive relationship between size class and activity, with highest activity in the largest size class.

Table 25: Observed data for pooled size classes – tallowwood (*E. microcorys*)

DBH class	Scat	No scat	Total	Strike rate
200 (100–299 mm)	6	49	55	10.9%
350 (300–399 mm)	5	28	33	15.2%
450 (400–499 mm)	8	26	34	23.5%
550 (500–599 mm)	6	21	27	22.2%
950 (600–1299 mm)	9	18	27	33.3%
Total	34	142	176	19.3%

The linear regression model shows a strong positive correlation between size class and activity (R^2=0.9306) (Figure 6).

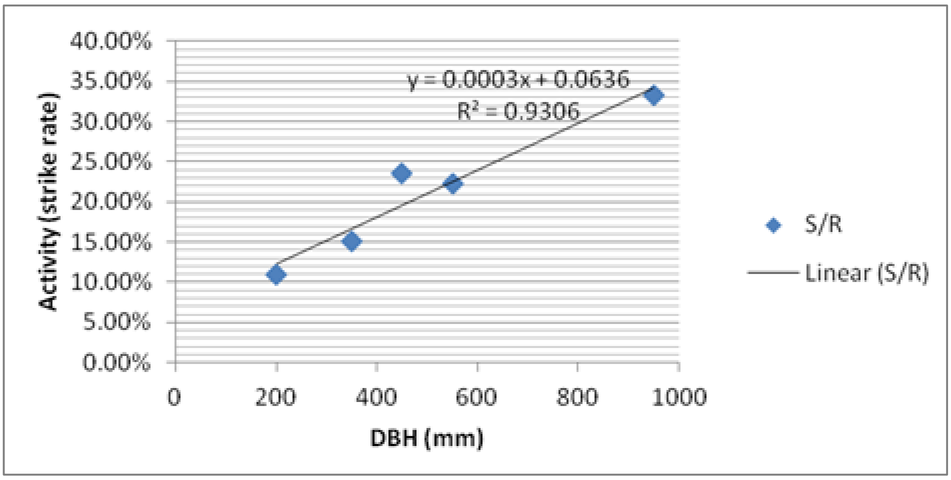


Figure 6: Size class of tallowwood versus scat strike rate

Correlation of feed tree data with spot assessment technique (SAT) activity

Following the recognition of a weak relationship between koala activity and mapped habitat classes (3Ai mapped, RN17 and koala modelled), it was decided to investigate the relationship between feed trees and SAT activity at a site level. One way of doing this was to calculate the correlation coefficient for the total feed trees within a SAT (0–30) and the activity (0–100).

The resultant correlation coefficient was found to be weakly positive (0.21) indicating that even at a site scale, the availability of feed trees is not strongly related to koala activity. Literature cites diversity and abundance as habitat determinates to koala abundance. Analysis of abundance of feed trees versus SAT activity (active sites only) resulted in a correlation coefficient of 0.198, while analysis of diversity of feed tree species at site versus SAT activity resulted in a correlation coefficient of 0.268. All results suggest a weak correlation between koala activity and feed tree availability, diversity and abundance. Smith (2004) found that koala feed tree diversity and abundance was one of the highest predictors of koala activity. This is a logical result and more appropriate analytical methods may improve the correlation outcome for this dataset.

5.3.2 Relationship between habitat mapping and koala occupancy

Summary

- The predictive model demonstrates a skewed distribution of probability of occurrence towards high and very high.
- There is a trend in higher koala activity within better quality habitat at the site scale for 3Ai-PCT koala class mapping; however, the majority of koala occupancy is across classes 1 and 2 (>15% feed tree crown cover) at the landscape scale.
- RN17 mapping shows reasonable correspondence with koala presence; however, the homogeneity of mapped classes may have resulted in this correlation, as lack of discrimination between classes limits the overall usefulness of the mapping at an operational scale.

3Ai-PCT mapping

Table 26 summarises activity by 3Ai assigned koala class. SAT activity classes were overlain with 3Ai mapped koala habitat classes. Several trends can be noted in the data, illustrated in Figure 7.

Table 26: SAT site occurrence by activity class and 3Ai koala habitat class

	SAT activity class			
3Ai koala class	**High activity**	**Normal activity**	**Low activity**	**Total**
Koala class 1	4	10	7	21
Koala class 2	4	13	12	29
Koala class 3	3	3	1	7
Non habitat		1		1
Total	11	27	20	58

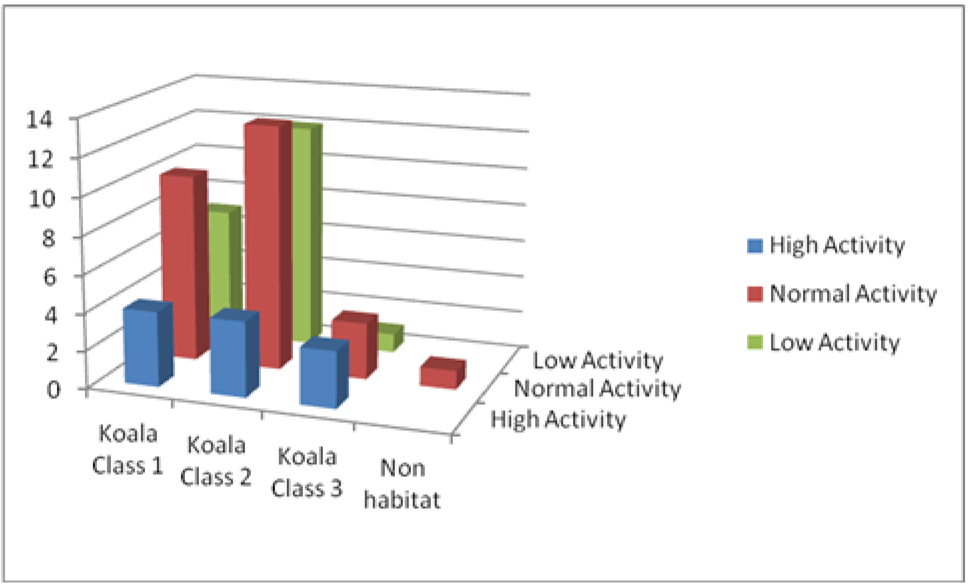


Figure 7: SAT sites by activity class and 3Ai koala habitat class

RN17 mapping

Table 27 summarises the results from SAT survey by RN17 'likely' koala habitat. SAT activity classes were overlain with RN17 koala habitat classes (Appendix E). At least two trends can be noted in the data, illustrated in Figure 8:

- The vast majority of activity classes fall within moderate classed habitat.
- There is a large correspondence of normal activity within moderate habitat.

These trends are consistent with the non-discrimination of koala habitat quality at the landscape level when using RN17 mapping and assigned koala classes.

Table 27: SAT site occurrence by activity class and RN17 habitat class

	SAT activity class			
Koala habitat class	High activity	Normal activity	Low activity	Total
High likely	1	2		3
Moderate	8	34	11	53
Low likely		1		1
Unsuitable		1		1
Total	9	38	11	58

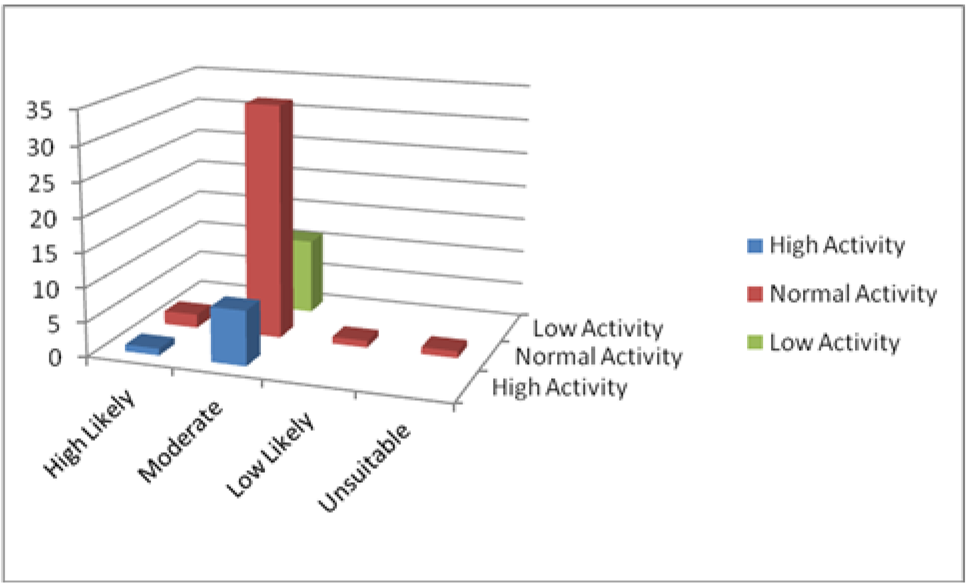


Figure 8: SAT site occurrence by activity class and RN17 habitat class

Modelled habitat

Correlation of predictive model of koala habitat probability of occurrence (POC) with SAT activity

A total of 57 pairs (across four state forest areas) were used in the correlation analysis, including a selection of the current SAT data available from the recent surveys, both stratified and grid data. Many SAT sites were excluded because they were inactive sites, were duplicates or they fell within the same grid cell in the model. In these cases, the highest activity site was retained. The results of the correlation analysis are illustrated in Figure 9.

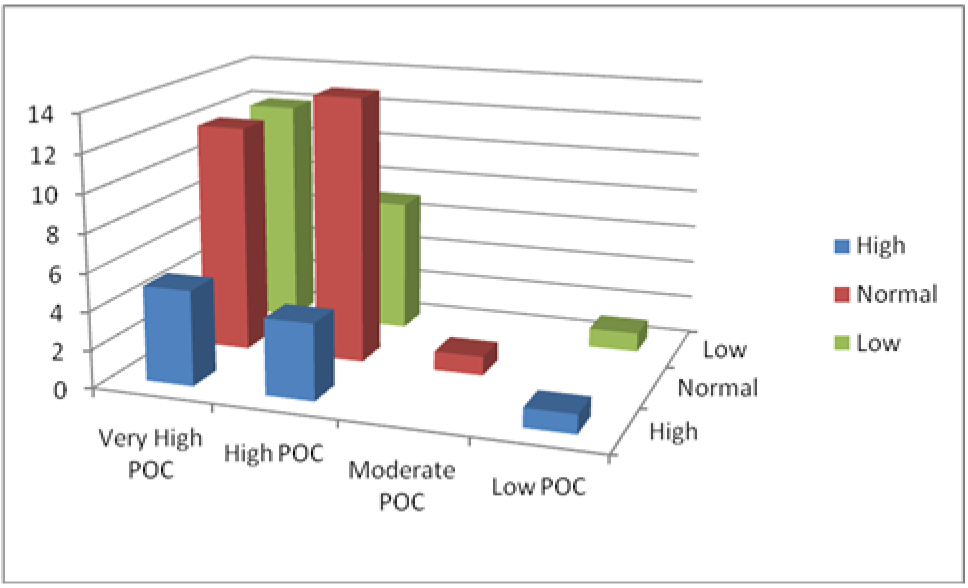


Figure 9: Count of SAT sites and activity by KHM class

In addition, the data was transformed in an attempt to correct for observed non normal distribution using a 0.65 threshold for non-suitability and suitability. The majority of SAT activity fell above 0.65. A log2 transformation was applied to the SAT activity and a power5 applied to the POC. While this rescaling has resulted in a greatly improved distribution of data, the overall relationship is still poor. A co-efficient of 0.0015 was resultant, indicating a weak positive relationship between SAT activity and predicted koala occurrence (Figure 10).

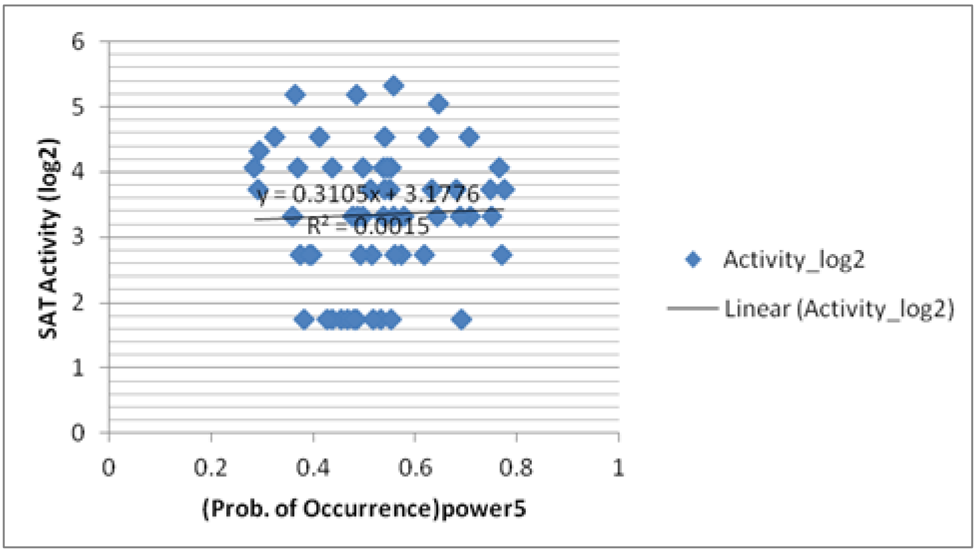


Figure 10: Transformed SAT activity (y axis) versus probability of occurrence (x axis)

Observations:

- SAT activity is almost always zero at sites below the 0.65 probability of occurrence threshold. This suggests the model is reasonably accurate in identifying areas that are unsuitable or of low suitability.
- Above the 0.65 threshold, activity scores are highly variable. This pattern is common in ecological studies that try to relate animal abundance to predicted habitat suitability. The pattern can arise if:

  a. large proportions of moderate to high quality habitat is unoccupied at the time of survey, potentially representing a sink population (i.e. due to past disturbance events such as fire, drought, predation, disease or socio-biological factors unmapped), and/or

  b. methods to assess activity are limited and only detect a small portion of sites that are actually occupied.

Landscape analysis

Summary

- Generationally persistent populations were found within all pilot state forest areas since 1990.
- Disturbance and structure showed a correlation with activity, however this depends on the accuracy of mapping data at the landscape level.
- Clouds Creek pilot area was identified as having the most currently unoccupied habitat of all the pilot areas surveyed (78%). Carwong State Forest was identified as the pilot area with the least currently unoccupied habitat (20%). Royal Camp occupied habitat of 58% conformed with Phillips' 2013 report on compartment 13, which recorded approximately 50% of habitat utilised.

Spotlighting

Royal Camp State Forest

More than eight hours of foot based handheld spotlighting, amounting to more than 16 person hours, was completed in Royal Camp State Forest along accessible vehicle tracks.

No koalas were recorded during spotlighting within Royal Camp State Forest over four evenings of spotlighting covering 35 independent 250 metre transects and effectively accounting for 35 hectares of survey coverage.

Carwong State Forest

More than four hours of foot based handheld spotlighting, amounting to more than eight person hours, was completed in Carwong State Forest along accessible vehicle tracks.

One koala was recorded over three evenings of spotlighting covering 18 independent 250 metre transects and effectively accounting for 18 hectares of survey coverage. The single observed koala was an adult male sitting in a grey box.

Maria River State Forest

One koala was spotlighted in the Maria River State Forest from the eight hours of two person spotlighting effort. It appeared to be a young female feeding in a small grey gum (*E. propinqua*). No other arboreal mammals were seen or heard during any of the transect surveys.

Clouds Creek State Forest

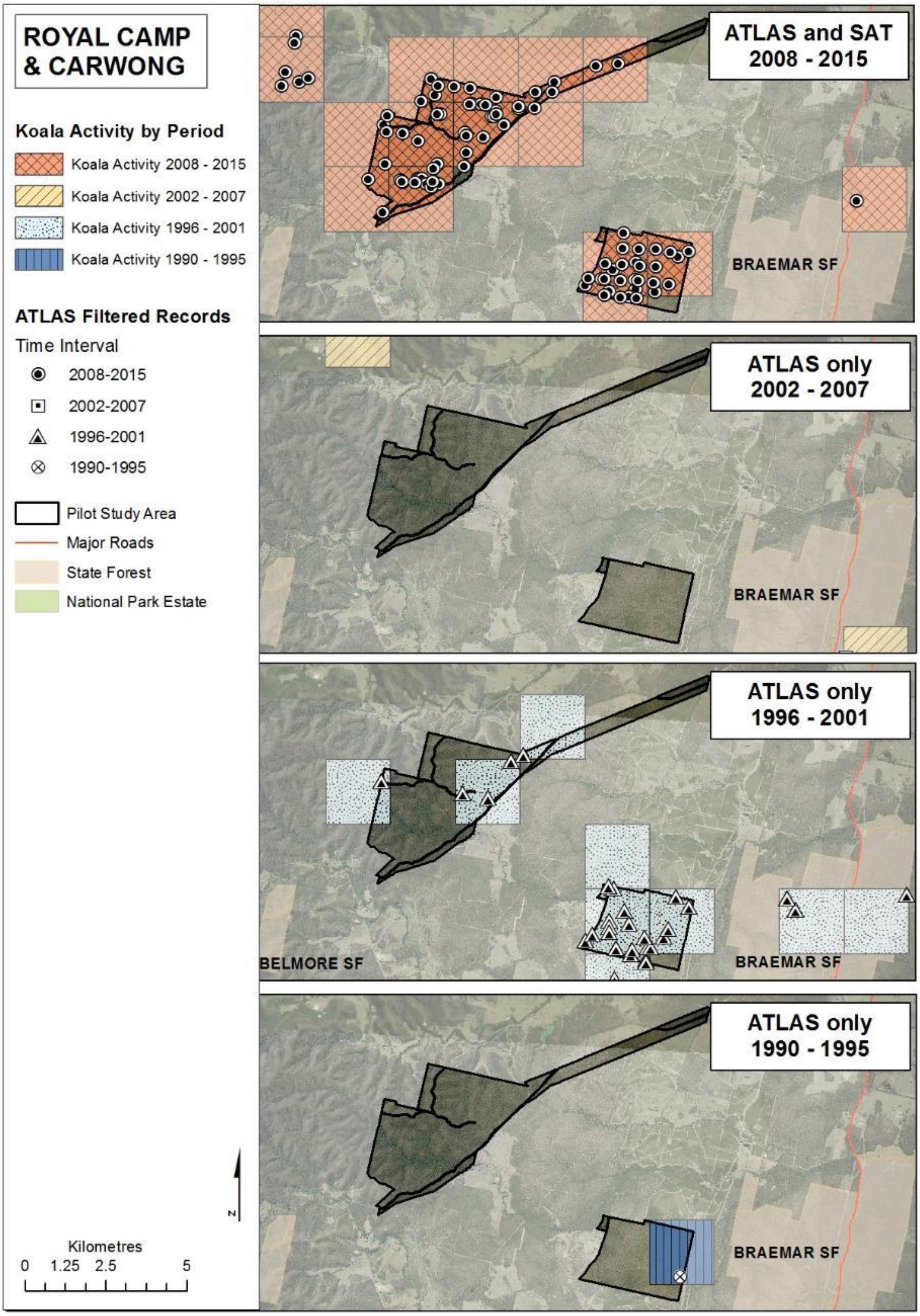
No koalas were sighted during Clouds Creek State Forest's eight hours of two person spotlighting effort.

Generational persistence

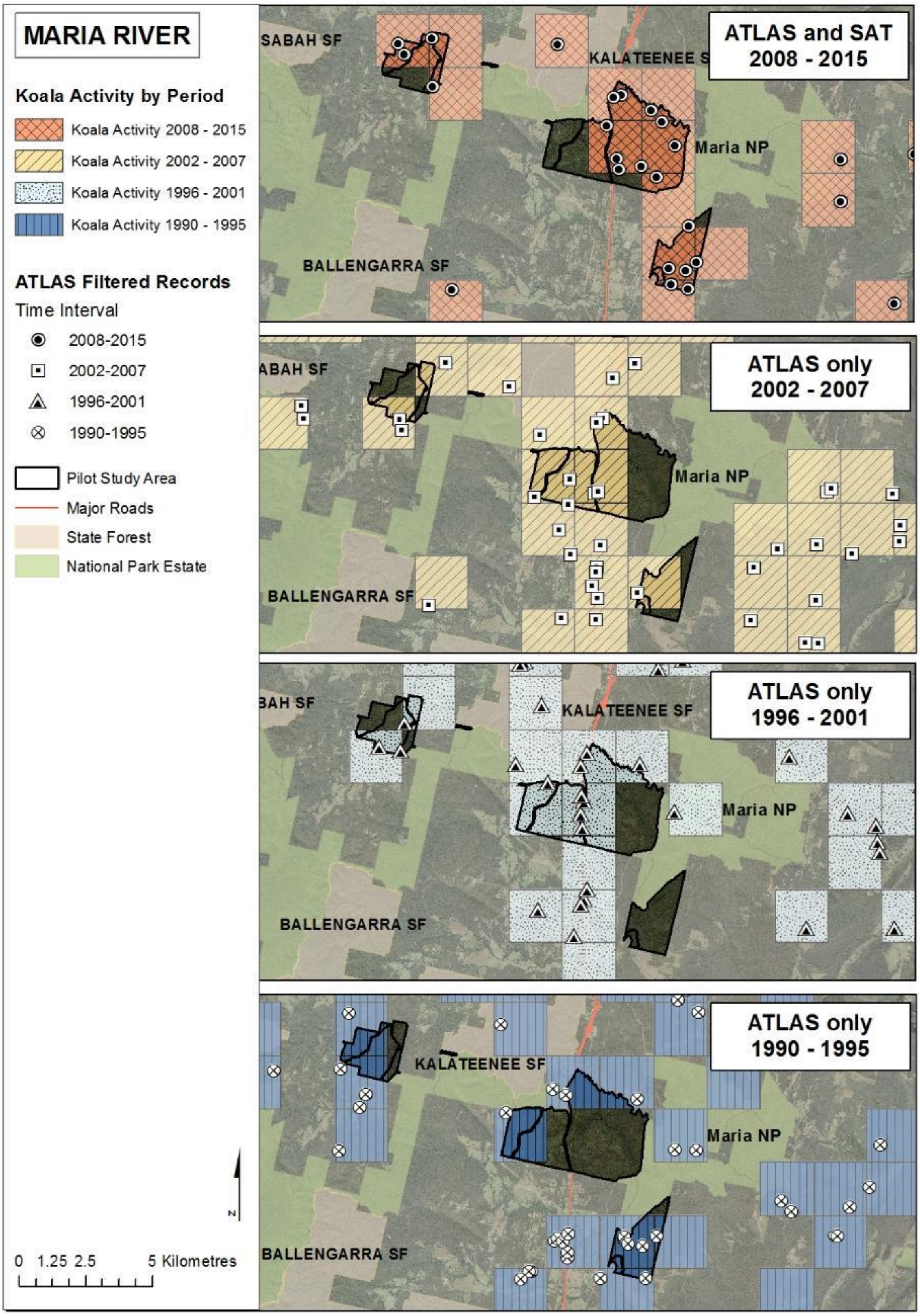
Persistence of koala occupancy was analysed using available koala records across four time periods from 1990 through to 2015. The results, shown below, reveal generally consistent koala occupation across the pilot study areas. In the absence of a more comprehensive survey dataset from all time periods, limited observations can be made; however, the precautionary principle and logic demands that this is seen as an absence of survey effort rather than an absence of koala persistence.

The most complete set of data and also the highest number of koala records for all areas belongs to the most recent period (2008–15). Older periods are more sporadic in terms of contributing data and this is reflected in the evidence of persistence of populations. Despite the non-systematic nature of data in the earlier periods, all pilot areas demonstrate reasonable consistency in occupancy.

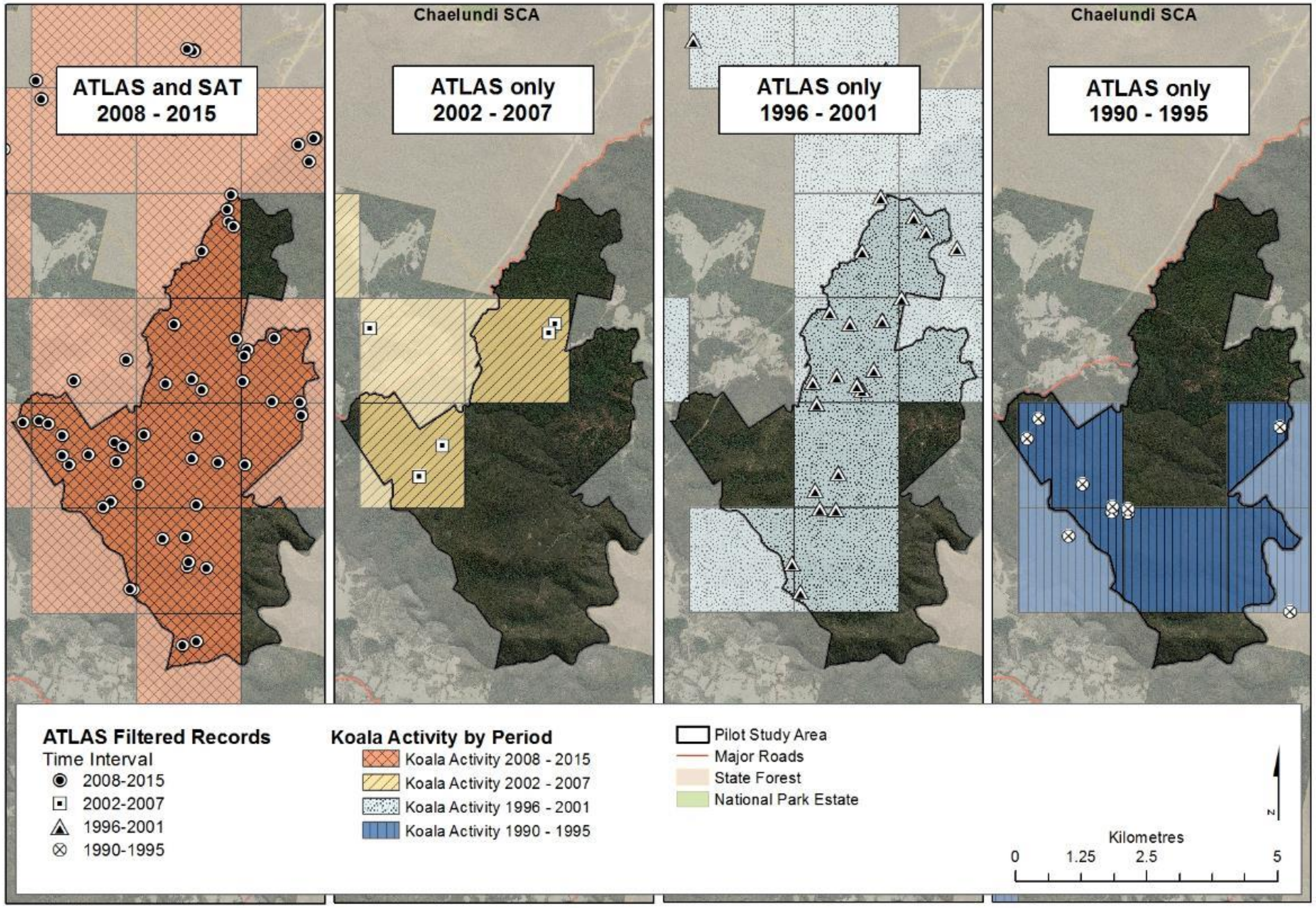
Maps 16 to 18 show generalised (2 kilometre grid – 400 hectares) occurrence of koala persistence over approximately six-year periods (the most recent period is seven years).



Map 16: Generational persistence – Royal Camp (east) and Carwong state forests



Map 17: Generational persistence – Maria River State Forest



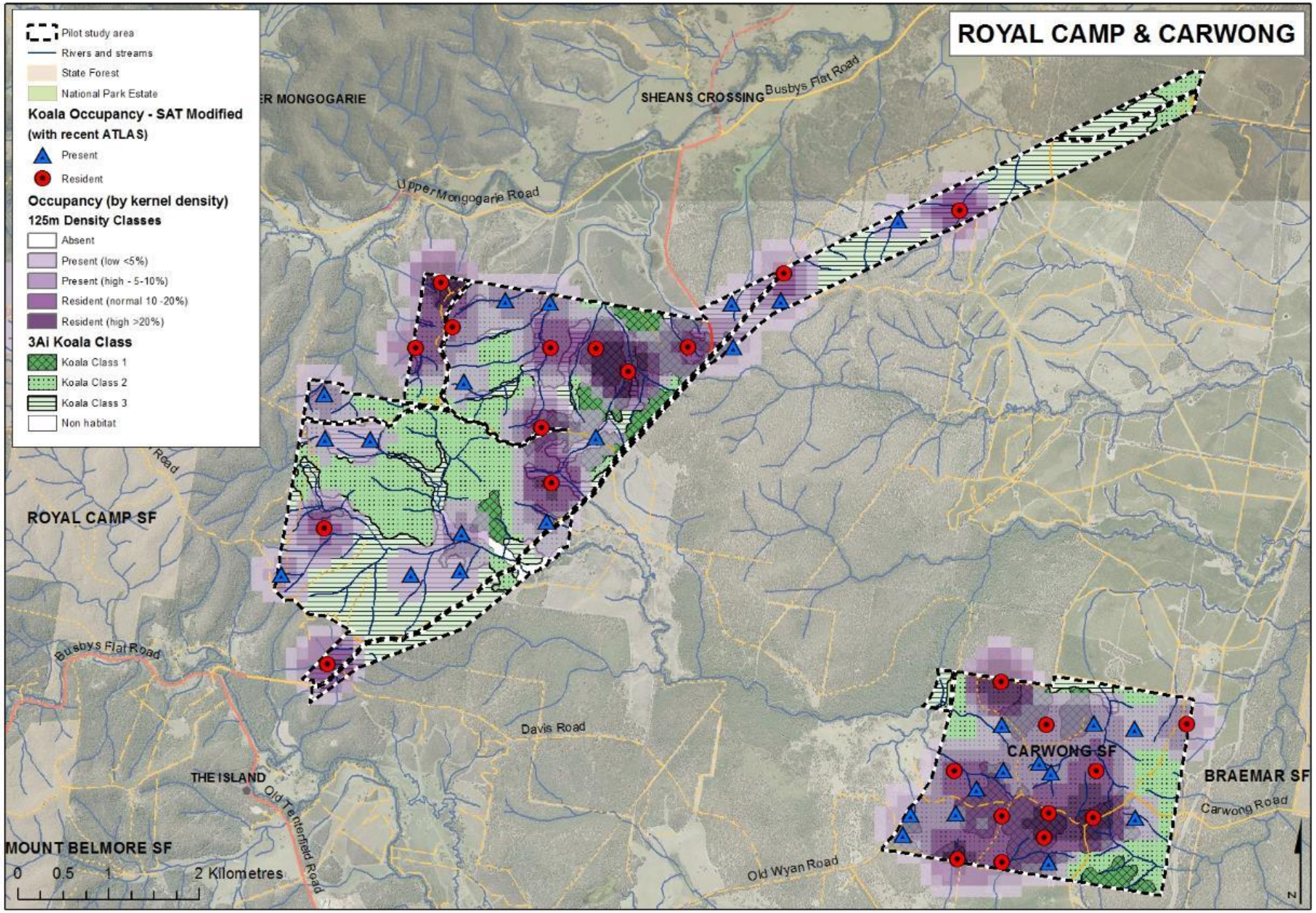
Map 18: Generational persistence – Clouds Creek State Forest (part)

Potential habitat utilisation

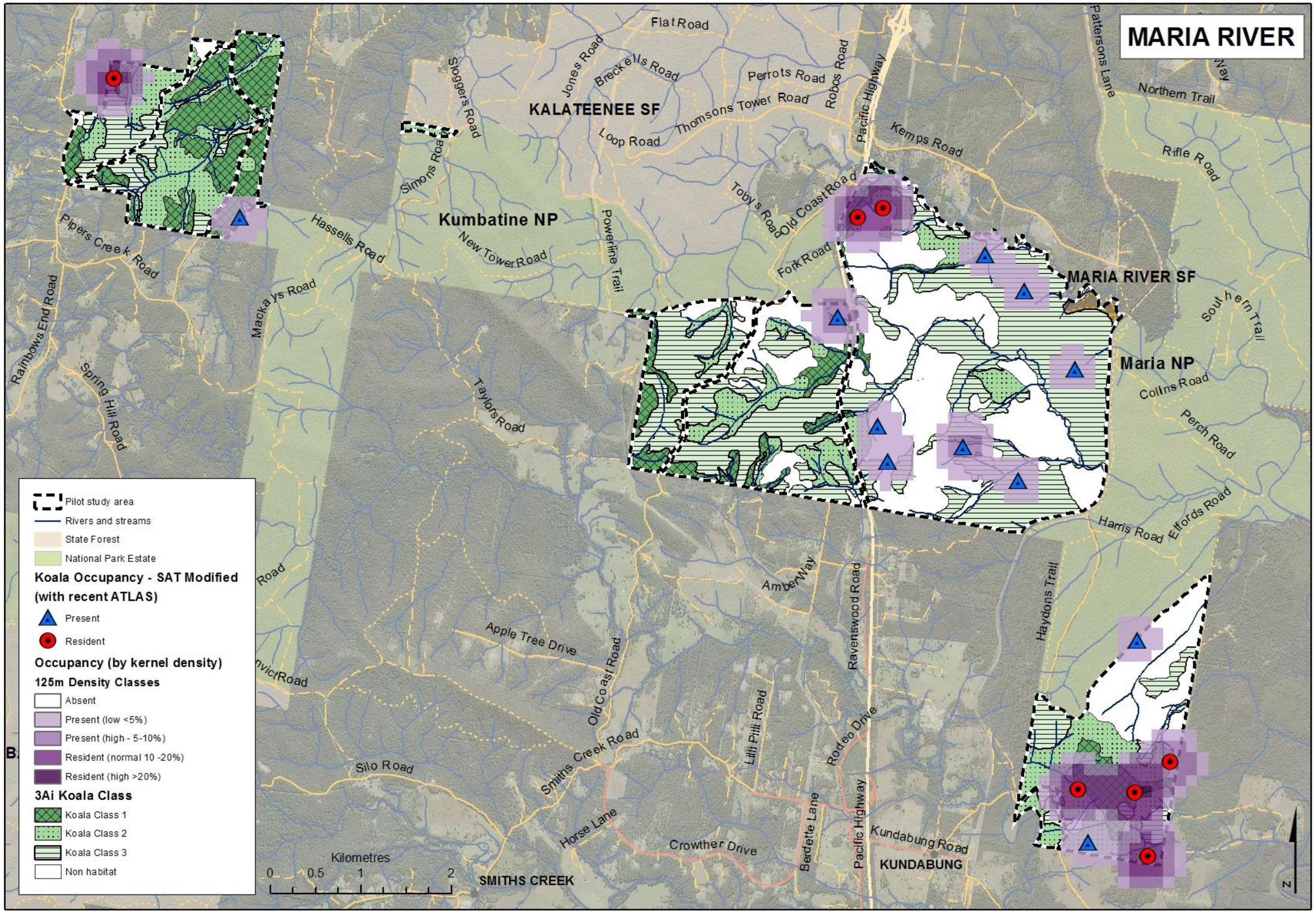
Potential habitat utilisation was mapped across the pilot state forest areas using kernel density analysis, as outlined in Section 5.2.4. The results of the analysis are presented in Table 16 and in Maps 19 to 21. The results indicate significant areas of utilisation across all pilot areas including areas considered to be 'resident' koala population, based on the Panel recommendation of greater than 10% activity.

Table 28: Potential habitat utilisation based on kernel density analysis

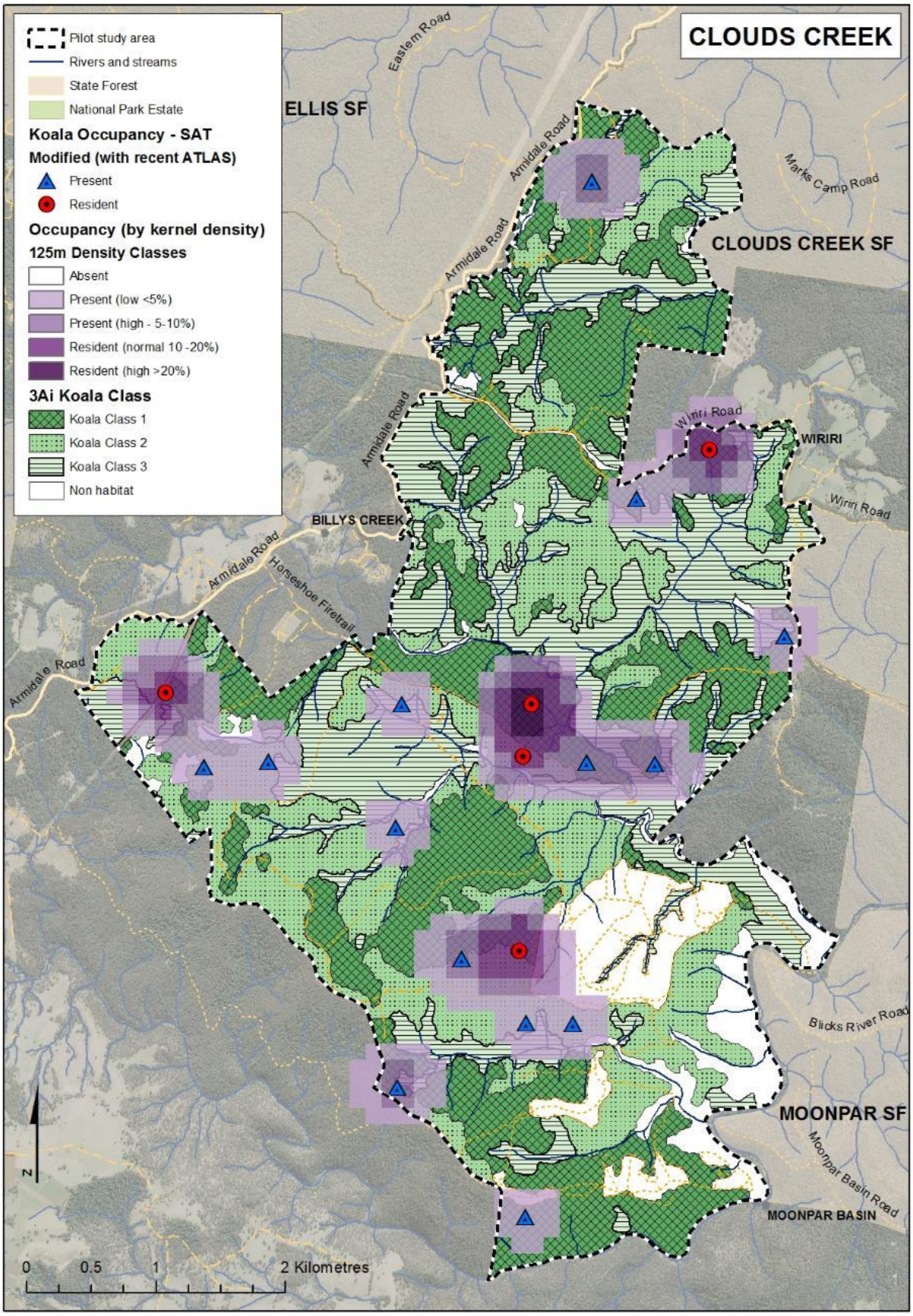
Utilisation class	Carwong SF	Maria River SF	Royal Camp SF	Clouds Creek SF	Total (ha)
Unoccupied	120	1,602	572	2,002	4,296
Present – low (<5%)	94	281	347	352	1,074
Present – high (5–10%)	173	91	225	135	624
Resident – normal (10–20%)	152	92	178	66	488
Resident – high (>20%)	61	3	51	9	124
Total (ha)	600	2,069	1,373	2,564	6,606
% Resident utilisation	35.5%	4.6%	16.7%	2.9%	9.3%
% Total utilisation	80%	22.6%	58.3%	21.9%	35%



Map 19: Potential habitat utilisation by 3Ai koala class – Royal Camp and Carwong state forests



Map 20: Potential habitat utilisation by 3Ai koala class – Maria river State Forest



Map 21: Potential habitat utilisation by 3Ai koala class – Clouds Creek State Forest

Habitat determinates

Structure

Structure class was mapped into three broad classes as per Table 29 below. The mature and over mature class accounted for approximately 50% of all mapped area. Comparing this result with the diameter at breast height recorded for trees within SAT survey sites and the resultant analysis of mean size class, some caution should be exercised. 3Ai field survey recorded the highest structure class based on the dominant frequency of trees just slipping into the mature age classification. Therefore, minimal discrimination between mature and mixed classes may result at the landscape scale.

Table 29: Area of each structure class mapped

Structure class	Polygon #	Area (Ha)
Not assigned (not habitat/missed)	13	156.3
Mature and over mature (>50% of polygon)	301	4,131.9
Mixed (50:50 mature and regeneration)	151	1,278.1
Regeneration (>50% of polygon)	95	1,085.2

Table 30 and Figure 3 below detail activity by mapped structure class. Seventy-four per cent (74%) of all activity resides in the high class of structural maturity and 45% of all 'resident (>10% activity)' classed sites are identified within a more mature forest structure, across all pilot areas.

Table 30: Koala activity by structure

Row labels	Mature and over mature (>50% of polygon)	Mixed (50:50)	Regeneration (>50% of polygon)	Unassigned	Total
High activity	9	1		1	11
Normal activity	17	5	4	1	27
Low activity	17	2	1		20
Total	43	8	5	2	58
As a percentage	74%	14%	9%		

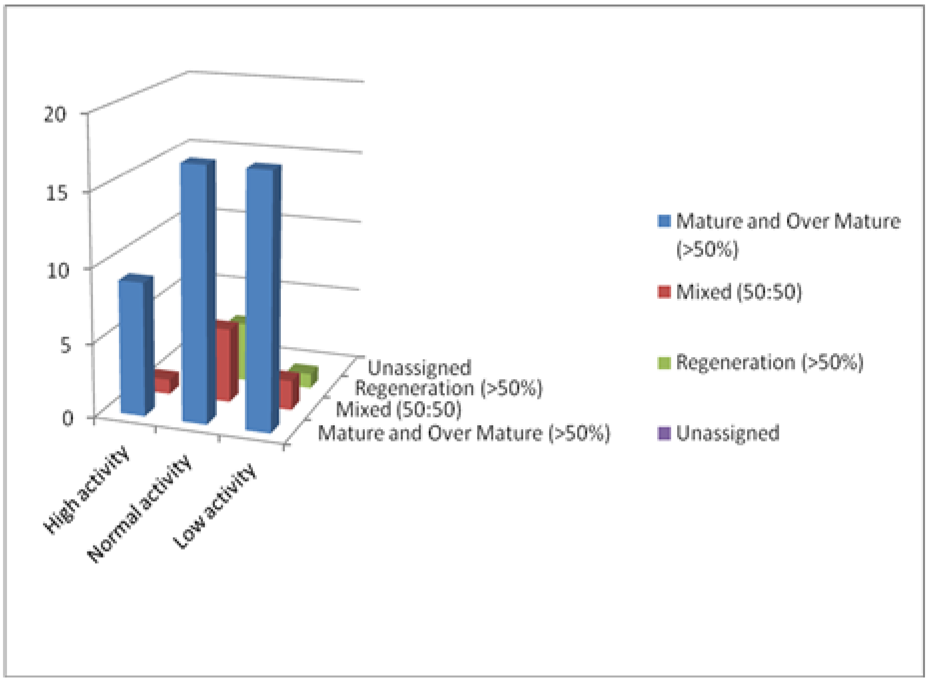
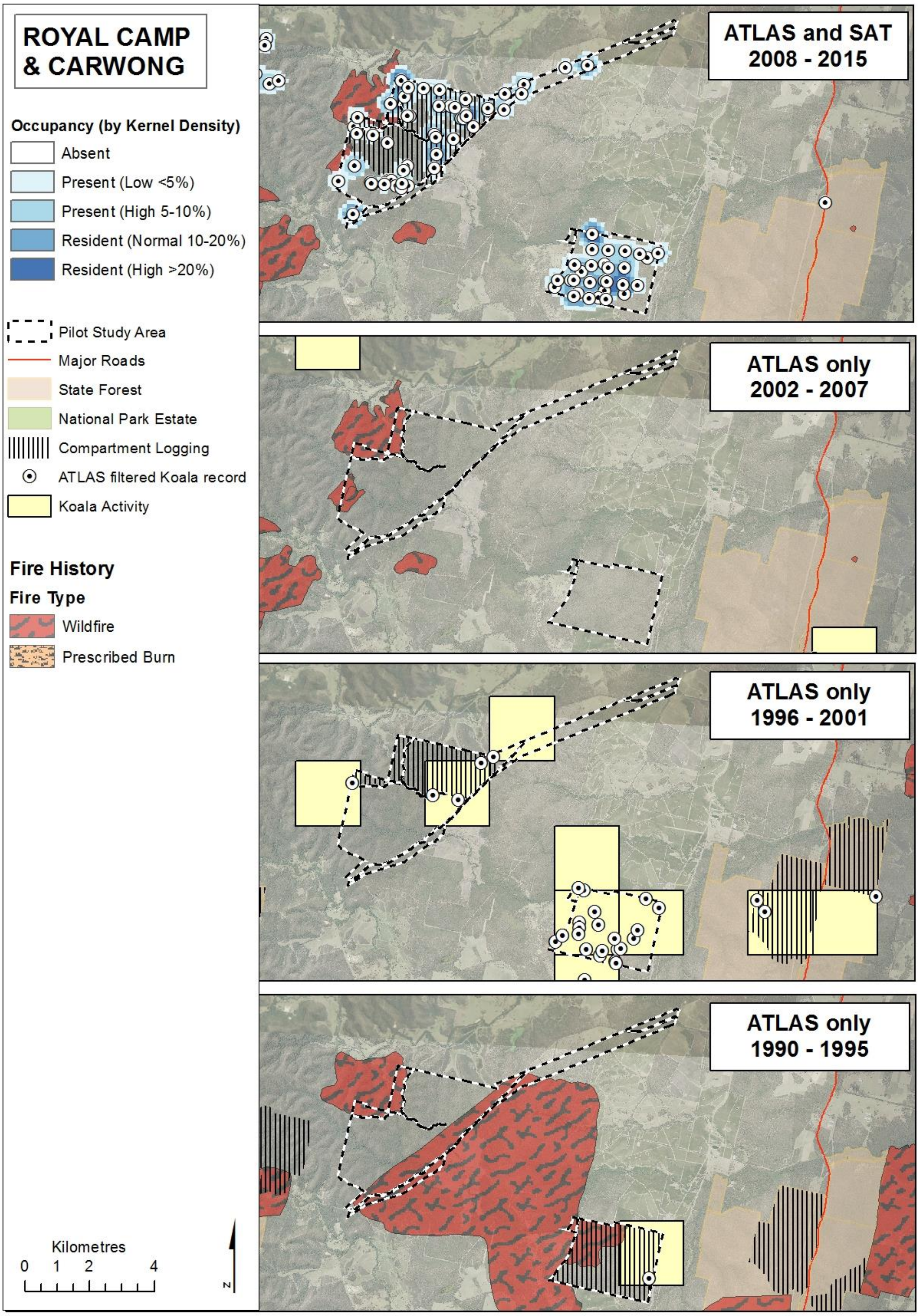


Figure 3: Correlation of activity by mapped forest structure

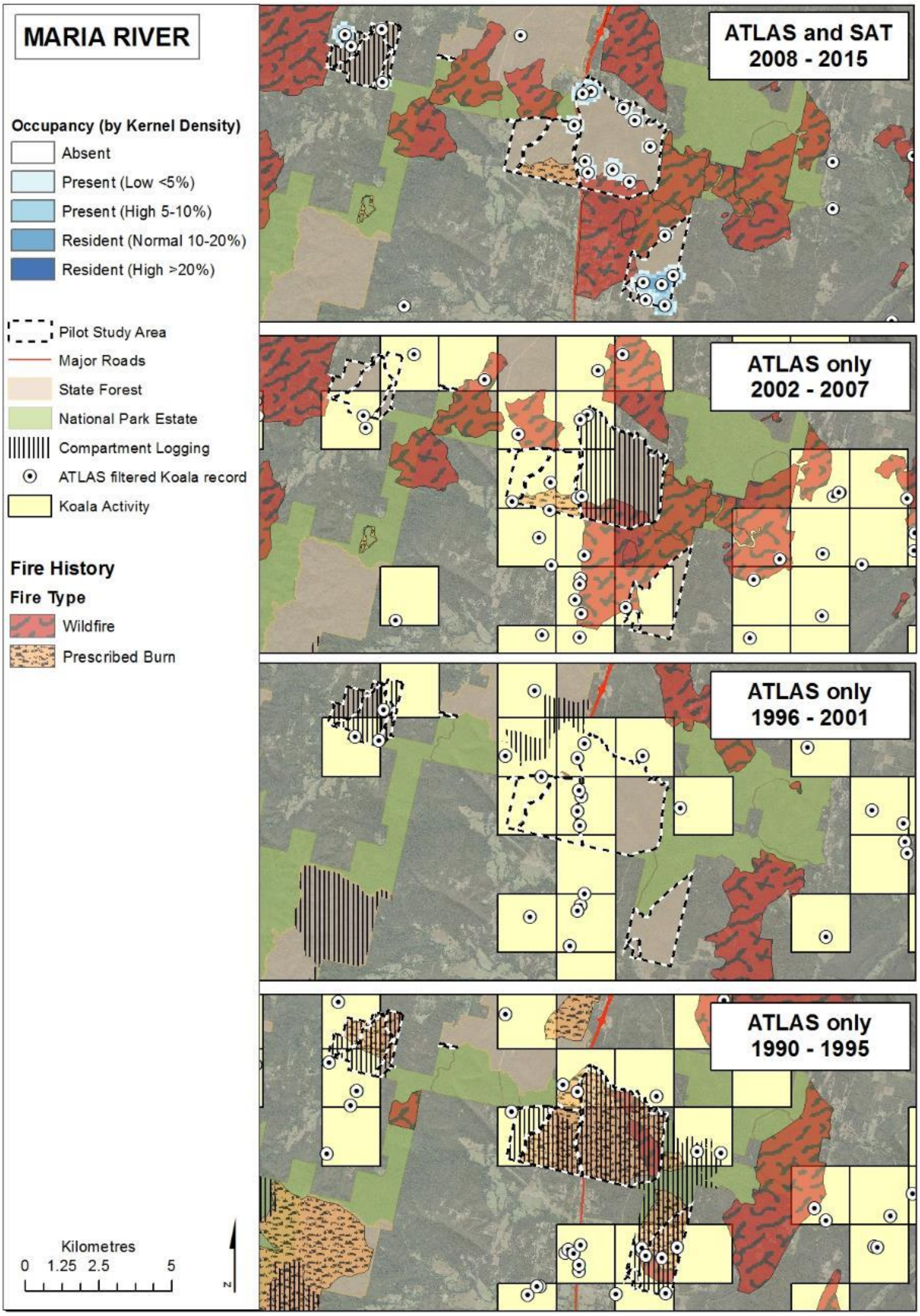
Disturbance

From a field based perspective, Clouds Creek appeared to be the most disturbed from logging and fire and appeared to be the most recent. Consultant data indicated Clouds Creek State Forest had been logged since 2009 and there has been frequent logging events within Billys Creek catchment over a four-year period. In addition to fire evidence in some areas prior to the recent logging event, a very hot fire occurred in 2013 (local residents pers. comm. 2015).

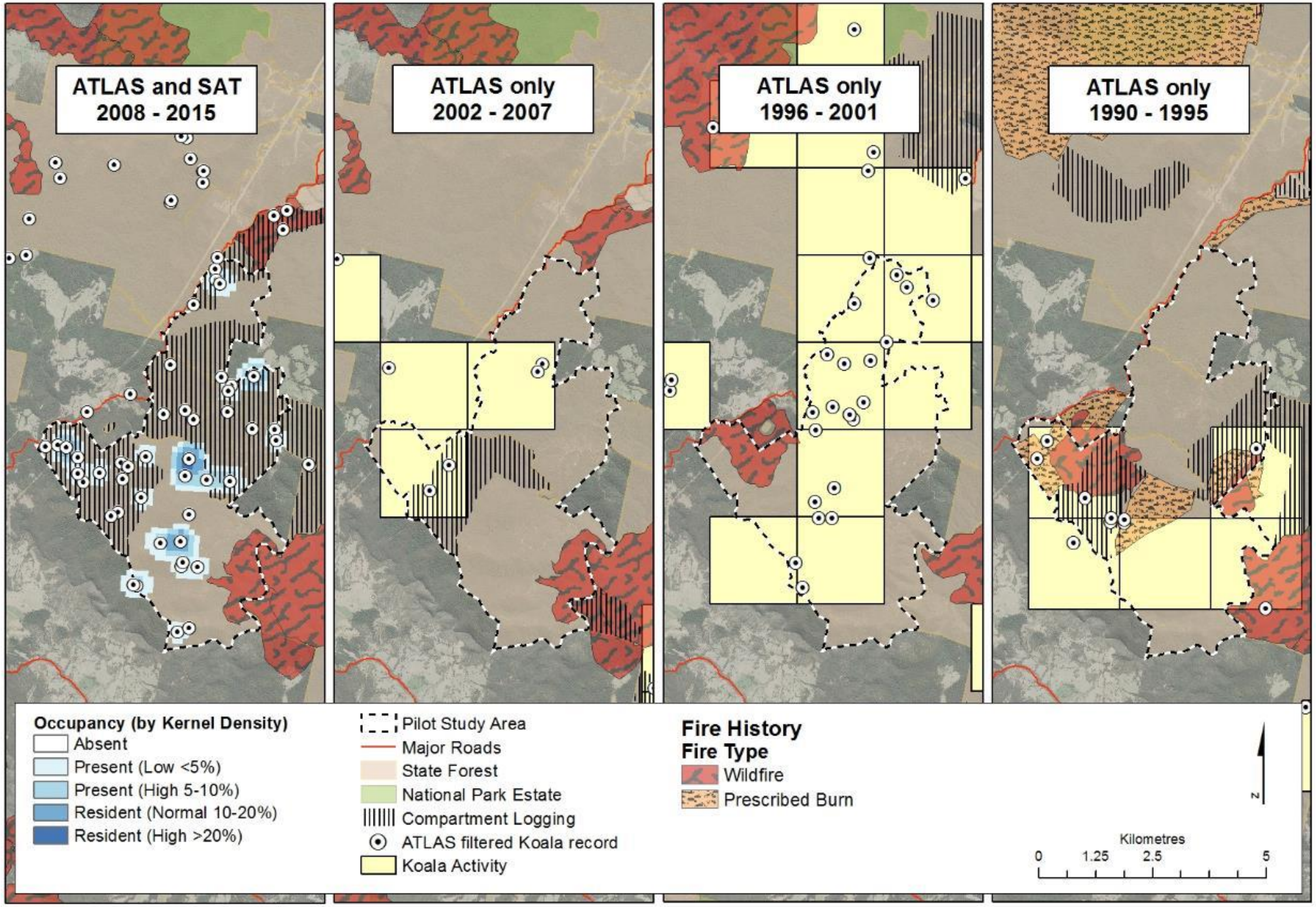
The impacts of disturbance events are reflected in the activity data against the context of perceived high quality habitat and potential for moderate to high density population. Maria River was the second most distubed pilot area from a field based perspective, with large areas recently logged. Areas in the western portion of Maria State Forest were heavily logged with very few trees greater than the 10 centimetres diameter at breast height in several of the sites allocated. Evidence of disturbance in Royal Camp and Carwong state forests is overall quite high. The eastern section of Royal Camp State Forest has been extensively logged, resulting in mosaics of young and small tree size classes dominating. Larger trees of most species are still present but in relatively low numbers. In relative terms, Carwong appeared to be the least disturbed by logging and fire. Having both wildfire and multiple, recent logging events absent from Carwong (for approximately 20 years) appears to correlate with overall highest occupancy compared with other pilot areas that have experienced multiple, more recent silviculture treatments.



Map 22: **Disturbance intervals for fire and logging – Royal Camp and Carwong state forests**



Map 23: Disturbance intervals for fire and logging – Maria State Forest



Map 24: Disturbance intervals for fire and logging – Clouds Creek State Forest

6. Map validation

Validation within the project was set at multiple levels and stages to include:

- 3Ai koala habitat assignment to each mapped polygon tested the assumption of a single PCT koala class assignment, by recording canopy variance within mapped PCT.
- Field koala habitat assessment using LKFT percentages was undertaken to validate both PCT and RN17 koala habitat classification and POC models.
- 3Ai was compared with POC models as a form of validating modelled habitat types.
- SAT occupancy survey data was compared with all habitat mapping options to determine the efficacy of mapping approaches and associated habitat classifications as surrogates for koala presence, protection and management.
- Scat collections were verified against a subset of scat samples identified by a fauna scat specialist (Appendix G).
- Spotlight survey was undertaken to validate high activity scat results within Royal Camp and Carwong state forests.
- Validation of koala class was undertaken by a consultant (Appendix J)
- Validation of koala occupancy was undertaken by a koala scat detection dog (Appendix K)

7. Discussion

7.1 Koala habitat classification implications within a state forest context

Aside from koala food tree availability, koala distribution across the landscape is primarily determined by regional and subregional factors such as geographic barriers (rivers, topography, geology/soils and vegetation formations) and climatic gradients (temperature and rainfall). Koala meta-populations, regional and subregional populations have been identified across NSW, defined by regional scale environmental determinants and constraints (Scotts 2013).

At the local scale, derived impacts (disease, predation, drought, fire, habitat loss, barriers and road kill) further influence koala distribution and habitat utilisation. Koalas have preferred tree species upon which they graze and shelter, which are known and differ by region. Eucalypt browse preferences vary locally and sub-regionally, as the interplay of environmental variables affects species distribution and leaf chemistry, depending on topographic position, soil fertility, tree size class, season and soil moisture (Moore et al. 2004).

Known koala distribution varies from a high or low density between and within specific geographical locations of which there is a source population (koala hub). Natural high or low density hubs reflect the quality of habitat at the local and subregion scale. The number of koalas observed in a hub will decline with distance due to factors mentioned above. Recent research has highlighted regional variation in habitat-occupancy thresholds and warned against applying general rules across different landscapes (Rhodes et al. 2008). Within hubs, habitat is either occupied or unoccupied for the same reasons listed above.

At the local habitat scale, it is important for land managers to distinguish between ‘temporary or transient’ and ‘resident’ koalas (koala home range). Smith (2015) states the importance of determining the difference between sink activity (where inward dispersal is high but mortality exceeds reproduction on average over time) from source activity (where reproduction exceeds mortality on average over time), as both categories should have very different specific protection and management approaches. It is also important to identify refuge areas where koala populations retract to in times of disturbance (fire, drought and logging) (Mathews et al. 2007; Ellis et al. 2010; Crowther et al. 2014 and Smith 2015).

Identification of the presence and the level of activity of koalas in an area is variable and inconsistent, owing to mobility across the landscape and the deterioration and low detectability of scats. Koala records are found across the landscape regardless of habitat quality. This variability creates a nutritional patchiness, such that species based assessments of habitat will likely result in overestimation of the availability of high quality habitat and food trees (Moore and Foley 2005; Moore et al. 2005). This is also the case for low density or sink populations, where high amounts of preferred habitat may be unoccupied at any one time.

These issues are a problem from a habitat mapping based perspective as koala occupancy does not generally conform to habitat quality on a landscape scale. The expert panel agreed that there is little value in relying solely on food tree categorisation of koala habitat to inform management options in areas subject to logging. Furthermore, the expert panel all stated that there is a need to incorporate koala socio-biology and disturbance history when attempting to determine priority koala habitat for protection.

This is problematic for koala protection within a forestry context, as koala and forestry rely on the same resource i.e. mature eucalypt forests. It is also a problem for conservation and land management, as large portions of the landscape can appear to be unoccupied by koala in a snapshot of time. For example, in wet, high fertile areas such as south Coffs Harbour and north Bellingen local government areas, koala habitat quality is considered high and distribution of ‘preferred’ habitat is extensive. This is also the case for low density populations of koala largely within dry, infertile landscapes on the north coast often defined as secondary B habitats under the Recovery Plan. Within these ‘low site quality – low density’ koala hubs, the majority of records are on lower slopes, flats and drainage features that correlate with a relatively higher fertility and moisture gradient. Some of these plant community types will be threatened ecological communities (TECs) and will have appropriate protection. Koala occupancy and habitat will no doubt extend beyond drainage lines and threatened ecological communities and their protection may be compromised due to the classification and spatial extent of secondary habitats.

The potential significance to koala populations of secondary habitat in comparison to primary or preferred habitat is underestimated by land managers. It is for this reason in particular, a subregional perspective is required. Koala hubs within dry and infertile areas should have special consideration and protection provisions equivalent to ‘primary’ classification status.

7.2 Habitat and management assumptions

Definitions of potential habitat used in current Koala Plans of Management are based on the Koala Recovery Plan (2008). The sequential classification of koala habitat based on feed tree preference, density, diversity (primary and secondary) and habitat fertility is intended to provide a mapped gradient of habitat suitability for koala across an area or region. Within a known koala hub, land managers may assume, as is implied by this classification, that better quality habitat for koala (more feed trees, more fertile soil) will contain more individuals, and / or koalas are more likely to inhabit these higher classes of habitat. This assumption is clear within all Koala Plans of Management as higher class habitat are prioritised for protection, management strategies, threat abatement and targeted survey and monitoring.

In reviewing the draft results of the pilot project, Phillips’ (2015a) stated that vegetation assessment and mapping/classification procedures can only ever be indicative (as opposed to definitive) in terms of their ability to accurately identify areas capable of being occupied by koalas. Phillips’ (2015a) stated ‘there may have been an underlying assumption/expectation that koala activity would be associated with higher quality habitat areas such that high habitat quality equals high probability of occupancy. However, this is rarely the case because other factors such as fire history/intensity and logging history/intensity, as well as koala socio-biology will need to be considered'.

Smith (2015a), in his review of the pilot, agreed with Phillips in that the pilot trial results for a state forest context 'supports the hypothesis that koala population are limited by unmapped social and or historical disturbance factors (e.g. fire, disease, hunting, logging and predation) which are not incorporated into predictive landscape and environmental models because they cannot be, or have not been adequately mapped'.

Smith (2015a) adds that 'the poor performance of predictive models (3Ai, Rn17 and POC Models) is consistent with the widely held hypothesis that koalas are frequently absent from areas of good quality "potential" habitat because of past disturbance from disease, hunting, urbanization, drought, fire, predation or other unknown causes. When koala populations are below carrying capacity for these reasons their distribution is likely to reflect aggregation for social or mating purposes as much or more than availability of food trees'.

The panel agreed that a two-tier classification system for koala habitat should be applied in a state forest context as a result of high disturbance regimes and unmapped variables. In areas of known occupation, identification of vegetation types as either 'suitable' or 'unsuitable' koala habitat should be the management trigger. Surveys should then be undertaken within suitable habitat to determine koala occupancy and habitat utilisation.

The panel agreed that to protect koala populations, the primary intent and focus should be to identify the location, distribution and extent of areas that are supporting extant/resident koala populations in addition to:

- managing them in an informed and sustainable manner
- retaining adequate areas of suitable but currently unoccupied habitat to enable ongoing processes of population recovery/expansion and contraction to be accommodated over time
- retaining linkages between habitat patches to assist ongoing processes of recruitment and dispersal
- minimising threatening processes to the maximum extent possible.

The overarching intent is to protect koala populations to ensure that permanent, free living populations are maintained over their present range. Currently unoccupied habitat should also be identified and a graded protection condition applied for management, based on mapped habitat quality class.

7.3 Koala occupancy

7.3.1 Survey limitations

The spot assessment technique (SAT) methodology for field surveys is based primarily on the presence/absence of koala scats under trees. Sampling large areas based on the indirect signs of koala presence is now a commonly applied survey method for a mobile and difficult to detect arboreal species.

However, environmental factors can influence the persistence and detectability of koala scats. The rates of scat decay is influenced by factors such as rainfall, humidity, temperature, location in the landscape and influence of invertebrates (Cristescu et al. 2012). Additionally, the detection of scats can be influenced by vegetation type. Searching can be more difficult in wet/fertile areas, associated with a dense ground and shrub layer, as compared to dry/infertile areas with less dense groundcover. Cristescu et al. (2012) found that wetlands had the worst detectability due to the dense groundcover, and also the quickest decay rate, while scats in drier locations with a simpler layer of litter had five times better detectability.

Observation errors and false negatives mean this method has the potential to underestimate koala presence in some circumstances. However on average, the slow decay rates ensure a low false negative error rate (Rhodes et al. 2011). Overestimation can occur where scat persistence and open forest combine to exhibit high activity. Alternative survey methods, such as spotlighting, can underestimate koala occupancy in dense forest types and overestimate in less dense forests, due to poor detectability (Smith 2004).

Compounding these limitations is the stratification of sites based on a grid. Key koala determinates – forest types with high diversity and abundance of feed trees, fertile parts of the landscape, mature forest structure and areas of least disturbance – may not be adequately surveyed with replication, or completely missed. Despite the density of SAT sites in this pilot, some gaps were identified in the geographic coverage and species diversity sampling at the local level. For example, despite the presence of several hectares of forest red gum PCT in Maria River State Forest, it was not sampled in the SAT survey and represents a limitation of not stratifying on potential koala vegetation types.

Accessibility of sites is a limitation of this method, including access to private property and in steep areas, wet/fertile dense vegetation types, and heavily disturbed areas resulting in dense weed or regeneration cover.

The influence of these factors on overall results in this study is open to debate, especially in Clouds Creek, where most of the limitations stated here were observed to be significant. The Dorrigo plateau had experienced high rainfall for every month of 2015 prior to survey of Clouds Creek, with over 100 millimetres in March and May and in excess of 200 millimetres in January, February and April. Rainfall on the weekend between the survey weeks was high, with in excess of 150 millimetres. Rainfall of this intensity would have some effect on the decomposition rates and physical washing of scats further into the leaf litter, potentially reducing scat detection.

Detection in Clouds Creek was further affected the density of shrub and ground layers and deep leaf litter. Accessibility was hampered by steep topography, viny thickets and dense regeneration. In the other pilot areas, with the exception of Royal Camp west, compounding limitations are likely to be low, given the systematic nature of the survey methodology and the environments being predominately dry and accessible with moderate disturbance, relative to Clouds Creek State Forest.

Survey limitations, average size of koala home range in a subregional context, potential activity between sites not assessed, and scat detectability and deterioration, all needs to be taken into account when assessing for koala occupancy. The validation component of this project used a koala scat detection dog to address some of these limitations.

7.3.2 Spotlighting

With results below expected from the spotlight survey effort, a number of inferences can be made that relate to this survey method. Spotlighting was introduced as a validation technique to measure against SAT activity results, especially for Royal Camp and Carwong, where high scat numbers may reflect scat persistence and detectability. False positive identification was also in question, as high numbers of brush-tail possums had been identified during the spotlighting effort. Similarly, koala scat detection in Clouds Creek found a high number of mountain brush-tail scats, which were not ‘indicated’ by the dog. This issue was partially resolved by scat identification via an expert (Dr Barbara Triggs), where a subset of scats were used as koala and possum references.

Underestimation and overestimation of koala activity can be a result of using only one method of koala survey. This is often the result of environmental factors contributing to the variability of scat detection, discussed in Section 7.3.1 above. In addition to this, spotlighting survey did not directly relate to SAT sites, as survey was limited to roads.

7.3.3 Spot assessment technique (SAT) activity

Smith (2015) stated that 'It is currently unclear how to interpret SAT scores. Low SAT scores may be indicative of either a) unsuitable habitat through which koalas are temporarily dispersing, or b) high quality breeding habitat in an area where koala densities are naturally low'. Phillips' (2013) report on compartment 13, Royal Camp, aligns with the latter view, as the habitat is capable of sustaining only a low density population.

Reclassifying activity to suggested categories of low activity (<10% to denote present/temporary koalas) and high activity (>10% to denote resident koalas), supported the analysis of the correlation between koala occupancy and habitat. However, all correlation results were not statistically significant for using a graded koala habitat map to manage koala occupancy. This data was used to identify habitat utilisation using kernel density analysis as an alternative to habitat mapping, where sufficient record data could inform the analysis. Categorising activity eliminated the noise created by currently unoccupied habitat SAT results. The expert panel agreed the only way to identify koala occupancy and habitat utilisation, is to use historical data and obtain current data through efficient koala survey techniques.

Smith (2015) also stated 'high SAT scores may be indicative of either a) sink habitat (where inward dispersal is high but mortality exceeds reproduction on average over time due to dogs, urbanization, drought, fire; or b) core (source) habitat (where reproduction exceeds mortality on average over time)'. Given the SAT results for Clouds Creek and to a lesser extent, Maria River SF, in combination with the degree of habitat disturbance (logging and fire) identified in the field, it would be reasonable to conclude that the high activity areas were sink habitats, as less than 30% total habitat utilisation was recorded, in addition to <5% of resident habitat area recorded.

Further analysis is needed of the subregional context of Royal Camp and Carwong state forests in relation to surrounding landscape habitat and disturbance, in order to understand the significance of this population. The activity results and Phillips' (2013) report both indicate that Royal Camp and Carwong state forests support extensive areas of koala occupancy and habitat utilisation, and that in compartment 13, at least 50% of the habitat is utilised and conforms to optimal utilisation of secondary habitat by a low density population. The project found that 80% of Carwong and 58% of Royal Camp State Forest is utilised, which supports Phillips' (2013) results. On this basis it can be concluded that habitat in Royal Camp and Carwong is source habitat, where reproduction exceeds mortality on average over time.

7.4 Koala habitat preferences

7.4.1 Koala food tree preferences and habitat classification

A list of koala feed trees (LKFTs) for the pilot areas was derived in consultation with Steve Philips (pers. comm. 2014). This list was based on the extensive tree utilisation data obtained from previous studies and Koala Plans of Management across northern NSW (Phillips pers. comm. 2014). No dietary or scat analysis was undertaken as part of this project; however, studies that have included scat analysis (Smith 2004) were reviewed and considered. This study found that grey gum was statistically the highest utilised species in all pilot areas with the exception of Clouds Creek. The overall low use of tallowwood was a reflection of its low frequency of occurrence across three of the pilot sample areas.

Numerous other species cited in literature and the Koala Recovery Plan 2008, are listed as secondary feed trees and some listed as secondary could be reassigned as primary. Regional hierarchical listing of species use across very different habitats does not reflect the true utilisation at the local or subregional scale. Grey gum is a good example of this. The project results did not support the inclusion of these secondary types as local koala feed trees, as their use was not independent of the determinate koala feed tree (KFT) list of species present at the site. As a precaution a more encompassing habitat classification was derived for the state forest context, which recognised that some secondary types are infrequently browsed upon to satisfy a year round requirement for new leaf growth and flowers high in nutrition (water, protein and energy) such as *Allocasuarina* spp. (Smith 2004).

To account for this exclusion of secondary feed trees in the classification, the EPA KFT threshold for class 1 habitat classification was set at 30% presence, not 50% as for 'primary' classified habitat. This acknowledged that classification set at 50% within a state forest context resulted in minimal spatial identification of 'primary' habitat. The additional species presented in the tree use data for each pilot area are viewed as habitat trees, represented as part of the vegetation type within which determinant local koala feed trees are present. This approach is supported by the relatively low strike rate of utilisation in the data and virtually non-existent independent use of local koala feed trees.

The identification of local koala feed trees should be based on statistically significant independent tree use data for local areas. Percentages of use should be viewed with caution as use of low frequency sampled species can present as inflated utilisation.

For regulation and prescriptive purposes within a state forest context, where loss of habitat is inevitable, the correct classification of habitat based on local koala feed trees and not secondary use trees is paramount, as the consequences can be high for koala habitat.

7.4.2 Diversity and abundance of koala feed trees

Koala feed tree diversity is an important habitat qualifier as it supports the koala nutritional requirements throughout the year.

The project findings show that Carwong State Forest presented with the highest feed tree abundance and diversity of all the pilot areas. This correlates positively with the overall result for koala occupancy and habitat utilisation, being highest in Carwong State Forest at 80%, with grey gum, forest red gum, tallowwood and grey box presenting as local koala feed trees.

Activity diminished across the other pilot areas reflecting lower koala feed tree diversity and abundance. In Clouds Creek, tallowwood was the only local koala feed trees with a habitat utilisation of 22%, Maria River presented with tallowwood and grey gum as local koala feed trees with a utilisation of 23%, and Royal Camp recorded utilisation of 58% with grey gum, forest red gum, tallowwood and grey box presenting as local koala feed trees.

Habitat utilisation should be viewed as a snapshot in time, and where habitat is unoccupied it remains suitable for future use. Smith (2004) reported that feed tree diversity explained the variation in koala scat abundance, more so than the frequency of a single feed tree, and is therefore seen as a primary determinant of koala abundance.

7.4.3 Structure

The structural component of a forest comprises trees of different size classes, and both size and structural diversity of forests correlates with higher koala occupancy (Lunney et al. 1996; Phillips' 2013; Smith 2004). This study found koala activity correlated with larger tree size classes and mapped mature forest components of the pilot areas. Smith (2004) found forest structure to be a key predictor of koala scat density after food tree species diversity and abundance, where scat abundance was greatest under trees with a diameter at breast height (dbh) of 40–80 centimetres. Phillips' (2013) reports similar preferencing for trees >30 centimetres in low fertility areas.

Mapped mature forests in the study accounted for approximately 50% of the area. The data for mean tree diameter at breast height and 3Ai field assessment indicate that these areas just make it into this age class. As a result of the broad classification class percentages, little discrimination is possible, and both the mature and mixed classes have similar proportions of mature and regeneration. Regardless of this, the majority of activity resides in these classes and aligns with Smith's (2004) conclusions that koalas prefer both mature and regrowth portions of forest structure for nutrition and shelter purposes.

7.4.4 Disturbance and soil fertility

Koalas are sensitive to forest loss and fragmentation (McAlpine et al. 2006; Rhodes et al. 2006, 2008). Disturbance and soil fertility proved to be lacking in discrimination at the local scale as a result of the small area of the pilot study and dominant management regimes within a state forest, namely logging and fire.

Soil fertility is assumed to be better within the lower areas of the landscape that correspond to drainage lines and lowland flats. Increased soil moisture is also assumed to correspond to these areas and distribution of activity can be viewed against these topographic positions. Phillips' (2013) found occupancy correlated with drainage lines, and this project indicated the majority of activity is in close proximity to drainage features in dry/infertile environments such as that represented in Royal Camp, Carwong and Maria River state forests.

Logging history and fire data were too coarse to determine specific site impacts on koala occupancy. From a field based perspective, Clouds Creek appeared to be the most disturbed from logging and fire and the most recently affected. Consultant data indicated Clouds Creek State Forest had been logged since 2009 and there has been frequent logging events within Billys Creek catchment over a four-year period. In addition to evidence of fire prior to the recent logging event, a very hot fire occurred in 2013 (local residents pers. comm. 2015). The impacts of disturbance events are reflected in the activity data for Clouds Creek, against the context of perceived high quality habitat and potential for moderate to high density population.

In relative terms, Carwong appeared to be the least disturbed by logging and fire. Having both wildfire and multiple recent logging events absent for approximately 20 years, appears to correlate with overall highest occupancy compared with other pilot areas that have experienced multiple, more recent silviculture treatments. This result aligns with Smith's (2004) findings that koala prefer areas of least disturbance. This scenario supports findings that a mixed age forest with dominant mature components provides koalas with optimal resource and shelter requirements within unnaturally disturbed environments.

8. Comparison of mapping methods

The following discussion focuses on the efficacy of the individual mapping approaches in identifying koala habitat for the purpose of managing the impact of native forestry operations in NSW state forests. It is a comparison of the suitability of individual methods for this purpose. It is not an assessment of the degree to which koala habitat mapping methods can be used to protect koalas, which is discussed in Section 7.1.

3Ai-PCT

3Ai-PCT is the best available option to identify and map graded koala habitat classes. 3Ai-PCT is the new standard for vegetation mapping and is accepted by vegetation experts in the field of ecological mapping. It is also the most accurate available method to identify vegetation communities, and is a relatively efficient method of mapping vegetation across large areas at a landscape scale.

However, achieving the required level of accuracy to identify koala habitat for management scale in a state forest context is expensive and time consuming, and accuracy can be variable. The associated costs were estimated as $6.60 per hectare ($40 000/6000ha), based on this project. Extrapolated across the coastal Integrated Forestry Operations Approvals (IFOA) regions, the cost would be $8.4m which may be prohibitive to the production of a map. This method also requires a high level of survey effort due to variation of vegetation types, which is increased in a disturbed environment. This variation, as well as the variable representation of koala habitat class within mapped polygons, means 3Ai-PCT is an inadequate method to predict koala habitat within a state forest context.

3Ai-PCT also yielded little benefit in terms of providing a graded habitat map to trigger koala conditions within a state forest context. This is primarily due to the correlation of the majority of koala activity with habitats consisting of greater than 15% local koala feed trees and the large proportion of forest estate with currently unoccupied habitat. As koala activity varies across the forest estate, there would be no guarantee that koalas and koala habitat would benefit from protection measures applied to specific areas.

Modelled probability of occurrence (POC)

The modelled probability of occurrence layer was found to over-estimate higher quality habitat across all pilot areas. This is likely a result of the model adopting bioclime data that surrounds koala records and therefore areas with a koala population will be over predicted. The model habitat classes have a similar habitat area and diversity to that of 3Ai as compared to other datasets. The 0.65 significance threshold applied in this project indicated that the model would capture the majority of koala activity and therefore could be used to trigger protective conditions similar to a suitable-unsuitable habitat map.

It is difficult to estimate the costs associated with modelling probability of occurrence across state forests, as the model is largely desktop based and most data inputs are available for analysis (e.g. temperature, rainfall, slope, fertility, aspect etc.). However, there would be costs associated with any additional field work that is required to improve or validate the model outputs.

Reassigned RN17 type mapping into DPI POC koala class

RN 17 Forest Type reassignment presented as a non-discriminatory map for the purpose of identifying koala habitat quality, as the majority of forest estate was classified as moderate likelihood of occurrence. Similar to the other approaches, its potential use as a koala habitat map to trigger koala conditions is possible if only used to identify suitable from unsuitable habitat. This broader application would be cost effective as mapping line work is complete and all that is required is an agreed reassignment of types based on presence of koala feed trees within the vegetation type down to 15% presence. RN17 is an accepted vegetation layer with known limitations, and as it is largely based on canopy species, it is therefore better suited to predict koala habitat within state forests.

A weakness of this approach is the limited ability to discriminate between koala habitat classes, which results in a high proportion of ‘moderate’ class across the landscape therefore underestimating better quality habitat areas. This uniformity may mean it is not suitable to apply graded conservation measures, as would be required in a state forest context. Another limitation with RN 17 Forest Type, is that the mapping only occurs on the state forest estate and loses its level of accuracy in the tableland forests of NSW. This restricts the ability to have cross tenure mapping and koala management outcomes.

Survey – habitat utilisation

The on ground koala activity surveys (occupancy survey) was conducted using the spot assessment technique (SAT). Independent validation of the findings of the SAT surveys was conducted using a scat detection dog. This enabled an assessment of the accuracy and efficiency of the spot assessment technique approach.

SAT survey methods yielded sufficient data to determine resident and transient koala activity. However its application was limited by cost, accuracy and environmental factors. A weakness of this approach is that scat identification is complex, with some scats often being confused with that of more commonly occurring species such as possums. Access to survey sites was often impossible due to dense vegetation or road access limitations. Differences in climatic variables also meant that the deterioration time of scats differed across the sampled areas, meaning that in wetter forests, scats could have broken down quickly and were not *in situ* when areas were samples. This could falsely indicate an absence of koala activity.

The accuracy of the SAT survey relies on repeated survey to determine koala occupancy. There are also survey design limitations that may result in underrepresented vegetation types not being surveyed and potential to miss high activity areas.

Dog detection could be a more accurate and cost effective method in areas of high groundcover and assisted in resolving some scat identification issues. It is also a more rapid method to determine koala presence in areas designated for logging. However, this, along with SAT surveys would need to be frequently repeated to be effective at determining koala activity and occupancy and is still constrained by the access limitations that were faced in the pilot study.

The costs associated with SAT survey methods means this approach would be expensive to apply at the state forest level. Based on the costs incurred through this project, survey costs $10 per hectare for person SAT searches, which would be $12.7 million across the coastal IFOA regions. This figure would be less if SAT searches were conducted in harvest areas only, however this would compromise the effectiveness of this survey approach, as it is intended to be a landscape assessment of koala activity.

While likely to be cheaper and faster than a person-based SAT search, the costs associated with dog detection are difficult to determine. This is an emerging ecological service and price would depend on the availability of dogs and, as above for SAT searches, the size of the areas searched (e.g. across all state forests or on a as needs basis of individual harvest areas). Regardless, the current pricing of scat detection dogs is prohibitive for the extent of state forest that would need to be surveyed (and repeated periodically).

9. Conclusion

The core purpose of this project was to determine whether the koala habitat maps tested (generated by 3Ai-PCT mapping, RN17 or a new predictive model) could be used to inform new rules for koala habitat identification and protection requirements in NSW state forests.

The project result show that the available methods tested cannot produce an accurate and reliable map of koala habitat at the local scale for the purpose of managing koala populations and associated habitat in a state forest context. Furthermore, these koala habitat maps cannot be used to indicate or predict koala occupancy.

Of the three different koala habitat mapping methods trialled, the project found:

- 3Ai-PCT mapping was the most reliable indicator of potential habitat quality at the local management scale. However, it is variable, costly and inadequate at accurately identifying habitat to the degree required for management purposes.
- Reassigned RN 17 types illustrated the least habitat discrimination at the local scale, and may have potential use in determining suitable and unsuitable habitat only.
- Predictive modelled habitat (POC) layer cannot currently identify probability of occurrence with any certainty at the local management scale.

The pilot project found that the variability of canopy species present within vegetation types is too great for determining percentage occurrence of feed trees and therefore habitat class at the level of detail required (1:5000 metres) for management in state forests. In addition to this variation, other factors, such as soil fertility, disturbance levels and koala socio-biological behaviour, play a significant role in determining habitat quality, some of which cannot be mapped.

The project findings indicated that koalas occupy suitable habitat to varying degrees for reasons other than floristic composition. All pilot areas were found to contain resident populations of koala and habitat utilisation was variable across the landscape. Limited areas of higher koala activity corresponded with; a higher abundance and diversity of local koala feed trees, trees and forest structure of a more mature size class (>30 centimetres and mature forest structure), and areas of least disturbance. Overall koala numbers, however, were most abundant in habitat areas with greater than 15% local koala feed trees in the canopy.

The effectiveness of a floristic based habitat mapping approach carries the risk of either missing key habitats or koala occupancy. The accuracy of maps is variable and their development would be costly across the Crown forest estate. Based on the findings of this project, it would be cost prohibitive to undertake a mapping program to identify graded habitat quality classes. Further, a product based solely on plant community types or any other vegetation data layer is too unreliable to protect koala populations, owing to the canopy species variation displayed within vegetation types, and the influence of other factors. In the absence of a guaranteed improvement to the protection of koalas, the use of these methods to develop a graded habitat map for use as a surrogate to identify and protect koala populations is not justified.

In reviewing the findings of this project, the expert panel concluded that future work should be directed at determining the known, existing koala distribution and resident population. They recommended that a koala habitat map using the methods assessed can only be used to distinguish suitable habitat from unsuitable habitat. Any landscape-scale protection provision attached to such a map would need to be both highly protective and follow precautionary conservation measures to protect both resident koala populations and manage unoccupied habitat to sustain the population into the future.

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[3] The development of the Koala Model was undertaken by an OEH officer in Coffs Harbour employed on a separate project. While not officially sanctioned, the Koala project team took an opportunity to utilise a local resource who was highly experienced in the use of spatial modelling techniques. OEH may further develop the approach at a future time.

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Appendix A – API Koala Habitat Mapping specifications

Feature delineation	
Reference scale for line work	1:5,000
Minimum remnant size	1 ha
Minimum size for delineation within larger patch of forest	1 ha
Minimum width for linear feature	10m
Plant Community Type Mapping	
Eucalypt PCT including representation as >30% emergent from non-Euc dominated PCT	Include
PCT	1 Only
PCT Variant or influencing API signature (pattern) 1. Understory 2. Euc Canopy (list species most dominant if present over 15%)	Yes/No Canopy Euc. sp. >15%
Likely EEC	Yes/No/identify
Non Eucalypt PCT	Non/identify PCT
Koala Habitat Classification	
Greater than or equal to 30 percent Local Koala Feed Tree	Class 1
Greater than 15% but less than 30 percent Local Koala Feed Tree species	Class 2
Less than 15% Local Koala Feed Trees	Class 3
No Local Koala Food Trees	Non Habitat
Structure (split PCT polygon)	
>50% Dominant Regeneration	Regeneration
>50% Dominant Mature	Mature and Over Mature
50:50 Regeneration and Mature	Mixed
Disturbance (>50% of polygon)	
Logging	Yes/No

Fire	Yes/No
Weeds	Yes/No
Bell Minor Die back	Yes/No
Feature confidence	
Field Validation	1
Transferred data	2
Unsupported	3

Appendix B – Fulcrum PCT Field Pro Forma

CCcc 88

Created	2015-05-12 05:40:30 UTC by rsd forest9
Updated	2015-06-22 08:54:36 UTC by rsd forest8
Location	-30.1583554657428, 152.599033828374

LOCATION

State Forest: Clouds Creek

Date: 2015-05-12

Time: 15:28

Plot size 50 x 50

Site marking: Unmarked

Recorders: Mark Fisher, Peter Knock, Robert Streeter, Paul Sherringham

NVIS LEVEL V

Structure and composition

Dominant stratum Tree

Structure Mature and Over Mature (>50%)

Upper stratum cover 40

Upper stratum height 35

Upper stratum

E. saligna, 35

Growth form Tree

Species name E. saligna

Cover (%) 35

Specimen No collection

E. microcorys, 5

Growth form Tree

Species name E. microcorys

Cover (%) 5

Specimen No collection

Mid stratum

4242, 10

Growth form Tree

Species name Lophostemon confertus (Brush Box)

Cover (%) 10

Specimen No collection

2270, 5

Growth form Tree

Species name Callicoma serratifolia (Black Watt

Cover (%) 5

Specimen No collection

3824, 5

Growth form Tree

Species name Acacia melanoxylon (Blackwood)

Cover (%) 5

Specimen No collection

3479, 5

Growth form Shrub

Species name Cryptocarya glaucescens (Jackwood)

Cover (%) 5

Specimen No collection

Ground stratum

8341, 10

Growth form: Fern

Species name: Calochlaena dubia (Rainbow Fern)

Cover (%) 10

Specimen No collection

8052, 5

Growth form Fern

Species name Blechnum cartilagineum (Gristle Fern)

Cover (%) 5

Specimen No collection

2431, 5

Growth form Sedge

Species name Gahnia aspera (Rough Saw-sedge)

Cover (%) 5

Specimen No collection

7749, 5

Growth form: Fern

Species name: Hypolepis muelleri (Harsh Ground Fern)

Cover (%) 5

Specimen No collection

Rapid PCT assessment

PCT 2227 Brush Box - Tallowwood - Sydney Blue Gum shrubby wet open forest of coastal hills and escarpment ranges, NSW North Coast Bioregion and the South Eastern Queensland Bioregion

Rapid koala habitat assessment

Keith class: Wet Sclerophyll

Dominant understorey: Rainforest

Soil fertility: Fertile

Koala habitat class Class 3 (<15%Local KFT)

Preliminary TEC field determination

Likely EEC: No - not TEC

PHYSIOGRAPHY eg. The site was a narrow incised channel with no obvious evidence of alluvial deposits. The creek line was marked by rocks and boulders.

Plot disturbance type: Logging

Appendix C – EPA modified rapid PCT vegetation API field survey form

Location: **State Forest Name:**					**Compartment No. :**			
Date		**EPA Site No.**			**Recorder(s)**			
AMG grid reference (if not using fulcrum)	zone	datum	Easting		Northing		Position in quadrat	Elevation(GPS)
Base Plot size	50m view shed radius sweep							

NVIS Level V (within 0.79 ha circle)

Structure
Regeneration (>50%)
Mature and Over Mature (>50%)
Mixed (50:50)
Upper stratum Cover (1-100%)
Upper stratum Height (m)
Min Max

Stratum	Growth form	Species name	PFC % for each species
Upper	Tree		
Upper			
Upper			
Upper			
Upper			
Mid			
Mid			
Mid			
Mid			
Mid			
Ground			
Ground			
Ground			
Ground			
Ground			

Growth form: T=tree, M=mallee tree, S=shrub, Y=mallee shrub, Z=heath shrub, C=chenopod shrub, **Cover %(PFC):** <1,1,2,3,4,5, 10,15,20,25,30,35%, etc. G=tussock grass, H=hummock grass, D=sod grass, V=sedge, R=rush, E=fern, F=forb, L=vine, A=cycad, P=palm, X=xanthorrhoea, U=samphire shrub

Rapid PCT assessment

PCT CODE: XXXX	
Euc. Canopy Variance >15%:	Species record:
Understorey Variance: Yes / No	

Rapid Koala Habitat assessment

Keith Class	Wet Sclerophyll				Dry Sclerophyll	
Soil Fertility	Fertile				Infertile	
Ground Layer	Shrub	Grass	Rainforest	Fern	Heath	Sedge

Koala Habitat Class	Class 1 (≥30%LKFT)	Class 2 (>15<30%LKFT)	Class 3 (<15%LKFT)	Non Habitat (no Local KFT)
Koala Evidence	Sight			Scat

Likely TEC

No			
Yes	Rainforest	Wetland	Eucalypt
Unsure	Rainforest	Wetland	Eucalypt

Plot Disturbance >50%

Logging
Fire
Weeds
BMAD
Other

Northern Rivers Koala Food Trees *(other species will be foraged and utilised when in association with those listed below, however, for the purposes of determining koala habitat classification, only the following will be assessed)*

1. Tallowwood (*E. microcorys*)
2. Swamp Mahogany (*E.robusta*)
3. Small Fruited Grey Gum (*E.propinqua*)
4. Parramatta Red Gum (*E. parramatensis*)
5. Forest Red Gum (*E.tereticornis*)
6. Slaty Red Gum (*E. glaucina*)
7. Orange Gum (*E.bancrofti*)
8. Grey Gum (*E.biturbinata*)
9. Large Fruited Grey Gum (*E.canaliculata*)
10. Grey Box (*E.moluccana*)
11. Yellow Box (*E.melliodora*)

Appendix D – FIDEL diagnostics and analysis

Canopy variance within Plant Community Types

The estimation of koala class for each polygon is generally driven by the PCT profile description and the Fidel diagnostic. Some PCTs experienced significant variation in the presence of koala feed trees. Where possible, this variation was recorded during the mapping process. As a guide, variants were recorded where a polygon was found to be dominated or co-dominated by a species not listed as being a major species for that PCT or where a non-listed KFT was present at >15% cover.

As an example, the *PCT 2171, Tallowwood - Small-fruited Grey Gum - Forest Oak dry open forest, South Eastern Queensland Bioregion and NSW North Coast Bioregion*, experiences significant variation in the Maria River Study area. Of the 664 hectares mapped, the clear majority (484 hectares) are recorded with a variant. The vast majority of the variants recorded for this PCT are non-feed tree species. Fidel derived KC for PCT 2171 is nominally a class 1 habitat PCT, only 212 of the 664 hectares are mapped as such. As this degree of variation has been identified it became clear that the assignment of a single koala class across a PCT would result in significant inaccuracy, albeit dependent on the PCT in question. Some PCT are less variable and therefore are more confidently defined into a KC such as Flooded Gum, Blue Gum, Swamp Mahogany types. The degree of survey and field knowledge held by 3Ai was determined to be superior to the Fidel derived Koala Class.

With this in mind, it is recognised that mapping of canopy variants can play a crucial role in the estimation of koala habitat class.

Table 1.5 PCT 2171 – Canopy variant and likely koala habitat mapped area

Variant name	Polygons	Ha		Likely Koala Habitat	Polygons	Ha
No variant	22	226.1		Not assessed	1	10.0
Corymbia intermedia	1	24.9		Class 1 (>=30%LKFT)	18	212.3
E. carnea	6	51.5		Class 2 (>15<30%LKFT)	20	198.6
E. globoidea	8	82.3		Class 3 (<15%LKFT)	22	190.4
E. pilularis	17	169.1		Non-habitat (no LKFT)	6	53.2
E. resinifera	2	13.9				
E. siderophloia	1	7.0		All PCT 2171		664.5
E. signata	4	26.4				
Melaleuca spp	1	3.7				
Syncarpia glomulifera	3	59.6				
All PCT 2171		664.5				

Use of FIDEL tables to derive expected koala class for Plant Community Types

The methodology for developing the plant community types included an analysis of the frequency and abundance of species which characterise the community. The software used for this purpose is known as FIDEL (Bedward 1999). FIDEL helps to isolate key species for the identification of each community and those common species which have significance in terms of their abundance. Fidelity results played a key role in describing plant community types identified in the vegetation classification for the Northern Rivers Region (OEH 2012). Using this data it is possible to estimate the expected koala class for any given PCT. As identified above, there is significant variability within some PCTs and this needs to be considered. Using the example of PCT 2171 again, below is an extract of the canopy species listed in the FIDEL data.

Table 1.6 FIDEL values for canopy species of PCT 2171

Ag-ID	Scientific Name	Group frequency	Group cover score	Non-group frequency	Non-group cover score	Fidelity class	Feed tree
1000-1071	Lophostemon confertus	57	2	20.5	2	+	N
1000-1071	Corymbia intermedia	48	2	15.6	2	+	N
1000-1071	Eucalyptus carnea	44	3	7.2	2	+	N
1000-1071	Eucalyptus siderophloia	37	2	9.7	2	+	N
1000-1071	Eucalyptus acmenoides	36	3	5.8	3	+	N
1000-1071	Eucalyptus largeana	0.3	2	0.0	0	+	N
1000-1071	Eucalyptus microcorys	74	2	19.1	2	+	Y
1000-1071	Eucalyptus propinqua	47	3	7.6	3	+	Y

Koala habitat class is measured by assessing the overall proportion of the canopy which is composed of koala feed trees. At any given location mapped as PCT 2171, the species composition will be variable and the koala class may vary from ‘Non habitat’ to ‘Koala Class 1’. Despite this variability and in the absence of any further information on canopy variance, the most likely koala class can be calculated using the group frequency and group cover score values. A simple formula which compares the sum of the frequency adjusted cover score (Group frequency x Group cover score) of feed trees to the sum of the frequency adjusted cover score of all canopy species is used.

$$\text{\% Koala feed trees} = \frac{\sum(\text{FreqF x Cover F})}{\sum(\text{FreqC x Cover C})}$$

where FreqF = Local Koala Feed tree frequency

CoverF = Local Koala Feed tree cover

FreqC = Canopy tree cover

CoverC = Canopy tree cover

For these calculations, group cover scores are converted from braun blanqet scale (1-6) to the median project foliage cover of that class. Table 1.7 below shows the results of this conversion.

Table 1.7 Group Cover Score Categories

Score	Median cover
1	2.5
2	2.5
3	12.5
4	35
5	62.5
6	87.5

Therefore, using the above median covers in the formula stated, the expected % feed trees can be calculated.

Table 1.8 Calculation of % feed trees for PCT 2171

Scientific Name	Group frequency	Group cover score	Overstory	Feed Tree	Median cover	Overstory frequency adjusted cover	Feed tree frequency adjusted cover
Lophostemon confertus	57	2	Y	N	2.5	1.4	0.0
Corymbia intermedia	48	2	Y	N	2.5	1.2	0.0
Eucalyptus carnea	44	3	Y	N	12.5	5.4	0.0
Eucalyptus siderophloia	37	2	Y	N	2.5	0.9	0.0
Eucalyptus acmenoides	36	3	Y	N	12.5	4.5	0.0
Eucalyptus largeana	0	2	Y	N	2.5	0.0	0.0
Eucalyptus microcorys	74	2	Y	Y	2.5	1.9	1.9
Eucalyptus propinqua	47	3	Y	Y	12.5	5.9	5.9
Sum of species						19.8	7.7

In the example above, the % koala feed trees for the PCT would be: 7.7/19.8 = 39%, putting the PCT into Koala Class 1.

Using this technique, the expected koala class was calculated for each PCT in the pilot area. The derivation of expected koala class for PCTs based on Fidel statistics is useful both as a check against API assigned koala class and also as a secondary measure where the API assigned koala class information is not available. Table 1.9 examines each PCT in turn for agreement between the Fidel derived koala class and the median API assigned class for each PCT in turn. Where a discrepancy existed between the API assignment and the expected Fidel koala class, a detailed review of the mapping and Fidel tables was undertaken. This process resulted in some refinement of the mapping data (in consultation with the mapping staff).

Total Canopy Frequency Adjusted Cover

The sum of the PFC scores for all canopy species moderated by their frequency. E.g. for a PCT with 3 canopy species:

*Total Canopy Frequency Adjusted Cover = Cover (species 1) *frequency (species 1) + Cover (species 2) *frequency (species 2) + Cover (species 3) *frequency (species 3)*

This value is the best estimate of the overall expected canopy cover of the PCT, including both feed tree species and non-feed tree species.

Total Feed Tree frequency Adjusted Cover

The sum of the PFC scores for all feed tree species moderated by their frequency. E.g. for a PCT with 3 feed tree species:

*Total Feed Tree frequency Adjusted Cover = Cover (species 1) *frequency (species 1) + Cover (species 2) *frequency (species 2)*

This value is the best estimate of the expected canopy cover of feed trees for the PCT.

Koala Feed Tree Relative Abundance

Feed tree abundance as a proportion of the overall canopy.

Appendix E – Reassigned RN17 habitat class

Type	League	Description	Habitat class
-1	Artificial Communities	Retention ex-plantation (Creation of retention areas in 2R establishment. These areas are predominantly on drainage lines and will be allowed to revert back to native vegetation.)	Unsuitable
218hNFA	Artificial Communities	Dunn's White Gum (accredited pre 1994 plantation under Native Forest Division control)	Unsuitable
9999	Not applicable	Not state forest (untyped)	Unsuitable
GeDSTQ1	Red Gum League	A red gum stand with an overall crown cover (stand density) of 50–75%. Within the stand senescent trees comprise >60% of the crown cover (D), mature trees comprise 10–40% (S) and regrowth comprises <10% (T). The stand is greater than 21 metres high.	Unsuitable
31/92	Maritime League	Paperbark / (Forest Red Gum)	High likely
47	Sydney Blue Gum / Bangalay League	Tallowwood – Sydney Blue Gum	High likely
47b	Sydney Blue Gum / Bangalay League	Tallowwood – Sydney Blue Gum (sub-type b)	High likely
51	Sydney Blue Gum / Bangalay League	Dunn's White gum	High likely
65	Grey Gum – Grey Ironbark League	Forest Red Gum – Grey Gum / Grey Ironbark – Roughbarked Apple	High likely
92	Red Gum League	Forest Red Gum	High likely
163a	Messmate – Brown Barrel League	New England Blackbutt (sub-type a)	Moderate
163b	Messmate – Brown Barrel League	New England Blackbutt (sub-type b)	Moderate
163c	Messmate – Brown Barrel League	New England Blackbutt (sub-type c)	Moderate
218h	Artificial Communities	Blackbutt (*Eucalyptus pilularis*) – hardwood plantation post 1997	Moderate
36	Blackbutt League	Moist Blackbutt	Moderate
37	Blackbutt League	Dry Blackbutt	Moderate
37a	Blackbutt League	Dry Blackbutt (sub-type a)	Moderate
37b	Blackbutt League	Dry Blackbutt (sub-type b)	Moderate
37O	Blackbutt League	Dry Blackbutt (O)	Moderate
39	Blackbutt League	Blackbutt – Spotted Gum	Moderate
48	Sydney Blue Gum / Bangalay League	Flooded Gum	Moderate

Type	League	Description	Habitat class
60	Grey Gum – Grey Ironbark League	Narrowleaved White Mahogany – Red Mahogany – Grey Ironbark – Grey Gum	Moderate
62a	Grey Gum – Grey Ironbark League	Grey Gum – Grey Ironbark – White Mahogany (sub-type a)	Moderate
62aO	Grey Gum – Grey Ironbark League	Grey Gum – Grey Ironbark – White Mahogany (sub-type O)	Moderate
62b	Grey Gum – Grey Ironbark League	Grey Gum – Grey Ironbark – White Mahogany (sub-type b)	Moderate
72/74	Spotted Gum League	Spotted Gum – Grey Box / (Spotted Gum – Ironbark / Grey Gum)	Moderate
74	Spotted Gum League	Spotted Gum – Ironbark / Grey Gum	Moderate
82	Grey Box – Ironbark League	Grey Box	Moderate
117	Scribbly Gum – Stringybark – Silvertop Ash League	Scribbly Gum	Low likely
119	Scribbly Gum – Stringybark – Silvertop Ash League	Scribbly Gum – Bloodwood	Low likely
126	Scribbly Gum – Stringybark – Silvertop Ash League	Stringybark – Bloodwood	Low likely
168	Messmate – Brown Barrel League	Silvertop Stringybark – Gum	Low likely
2/3	Subtropical Rainforest League	Yellow Carabeen / (Corkwood – Sassafras – Crabapple – Silver Sycamore)	Low likely
26	Dry and Depauperate Rainforest League	Viney Scrub	Low likely
41	Blackbutt League	Blackbutt – Bloodwood / Apple	Low likely
46a	Sydney Blue Gum / Bangalay League	Sydney Blue Gum (sub-type a)	Low likely
46b	Sydney Blue Gum / Bangalay League	Sydney Blue Gum (sub-type b)	Low likely
5/11	Subtropical Rainforest League	Booyong – Coachwood / (Coachwood – Crabapple)	Low likely
53	Sydney Blue Gum / Bangalay League	Brush Box	Low likely
53a	Sydney Blue Gum / Bangalay League	Brush Box / (sub-type a)	Low likely

Type	League	Description	Habitat class
53b	Sydney Blue Gum / Bangalay League	Brush Box / (sub-type b)	Low likely
6/23	Subtropical Rainforest League	Fig – Giant Stinger / (Myrtle)	Low likely
70/72	Spotted Gum League	Spotted Gum / (Spotted Gum – Grey Box)	Low likely
74a	Spotted Gum League	Spotted Gum – Ironbark / Grey Gum (sub-type a)	Low likely
74b	Spotted Gum League	Spotted Gum – Ironbark / Grey Gum (sub-type b)	Low likely
21	Dry and Depauperate Rainforest League	Hoop Pine	Unsuitable
s	Not applicable	Sub-species	Unsuitable

Appendix F – Koala Habitat Spot Assessment Form

KOALA HABITAT SPOT ASSESSMENT

SAT No: _____ / _____ **Recorder:** _______________

Date: ______/______/________

Easting: _ _ _ _ _ _ **Northing:** _ _ _ _ _ _ _

OR GPS site recording: Yes / No

1. Record site location details above.
2. Start at nearest Koala Food Tree (or tree with koala evidence) to sample point.
3. Thoroughly search ground surface within 1 metre of tree for a maximum of 1 minute.
4. Record trees species (use codes at right if cannot identify species), diameter at breast height and presence or absence of koalas and koala scats.
5. If a koala scat is found, cease search under that tree and progress to next closest tree.
6. Sample the nearest 30 trees of any species >10cm DBH.
7. For any opportunistic Koala sighting between sites, please record GPS point separately.
8. Record site information in 1 to 9 below.

Abbrev	Tree species
SM	Swamp Mahogany (*E. robusta*)
TWD	Tallowwood (*E. microcorys*)
FRG	Forest Red Gum (*E. tereticornis*)
SRG	Slaty Red Gum (*E. glaucina*)
SFGG	Small Fruited Grey Gum (*E. propinqua*)
GG	Grey Gum (*E. biturbinata*)
GB	Grey Box (*E. moluccana*)
OG	Orange Gum (*E. bancrofti*)
BBT	Blackbutt
IBK	Ironbark
MHG	Mahogany
SB	Stringy Bark
SBG	Sydney Blue Gum
Euc	Other Eucalypt
Oak	Allocasuarina sp.
Ang	Angophora sp.
BWD	Bloodwood
SG	Spotted Gum
BB	Brush Box
TURP	Turpentine
Mel	Melaleuca sp.
Acacia	Acacia sp.
Cal	Callitris sp.
Sclero	Other sclerophyllous
Rainf	Other rainforest sp.
Ex	Other exotic sp.

	Tree Sp.	DBH	Koala	Scat
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				

(*Circle* categories 1 - 5 below)

1. Soil Fertility: ***Fertile / Infertile***

2. Habitat ***Dry Sclerophyll / Wet Sclerophyll***

3. Ground layer/understory

Shrubby / Ferny / Grassy / Heath / Sedge

4. Age of scat: ***Old / Mixed / Fresh***

5. Mean % groundcover in search area:

< 30% ***30 – 70%*** ***>70%***

6. Distance from tree 1 to tree 30: ____ **m**

7. A/Level: evidence # / 30T x100 = _ _ %

8. No. of Koalas within plot: ____

9. Comments: ______________________________

____

____

____

____

_

Checked by: Date: / / Entered by: Date: / /

Appendix G – Scat sample validation

EPA Koala survey							
No.	**Date**	**Site**	**Tree #**		**Scat ID**	**Mammal ID - definite**	**Mammal ID -**
1	12/05/2015	RC	25		koala	Phascolarctos cinereus	
2	12/05/2015	RC	20		koala	P. cinereus	
3	12/05/2015	RC	30		koala	P. cinereus	
4	13/05/2015	RC	17		koala	P. cinereus	
5	14/05/2015	RC	10		koala	P. cinereus	
6	14/05/2015	RC	21		koala	P. cinereus	
7	14/05/2015	RC	29		possum	Trichosurus sp.	
8	14/05/2015	RC	11		macropod	(fragment only)	Macropus sp.
9	15/05/2015	RC	5		koala	P. cinereus	
10	15/05/2015	RD41	16		possum	Trichosurus sp.	
11	no data	RC	28		possum	Trichosurus sp.	
12	12/05/2015	RC	14		possum	Trichosurus sp.	
13	14/05/2015	RC	1		macropod	(fragment only)	Wallabia bicolor
14	no data	RC	20		koala	P. cinereus	
15	no data	RC	23		possum	Trichosurus sp.	
16	13/05/2015	RC	23		possum	Trichosurus sp.	
17	28/05/2015	Clouds Creek			koala	P. cinereus	
		Sat 22					
		460019/6659543					

No.	**Date**	**Location**	**Tree #**	**DBHOB**	**Scat ID**	**Mammal ID - definite**	**Mammal ID -**
1	11/05/2015	Royal Camp East Site	16		possum	Trichosurus sp.	T. vulpecula

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2	22/04/2015	RC-2F Spot G	1	42cm	possum	Trichosurus sp.	T. vulpecula
3	22/04/2015	RC-	8	39cm	possum	Trichosurus sp.	T. vulpecula
4	no data	RC-	26	22cm	?koala		Phascolactos cinereus
5	22/04/2015	RC-	16	53cm	?possum		Trichosurus sp.
6	no data	RC-	18	47cm	possum	Trichosurus sp.	T. vulpecula
7	23/04/2015	RC - 35C?K	30	21cm	?possum		Trichosurus sp.
8	23/04/2015	RC - 35C?K	16	24cm	?koala		P. cinereus
9	23/04/2015	RC - 35F	14	47cm	possum	Trichosurus sp.	T. vulpecula
10	no data	CW6F	28	30cm	possum	Trichosurus sp.	T. vulpecula
11	no data	CW1	13	57cm	possum	Trichosurus sp.	T. vulpecula
12	no data	CW1	28	25cm	possum	Trichosurus sp.	T. vulpecula
13	no data	Carwong - C15			possum	Trichosurus sp.	T. vulpecula

Appendix H – Plant community types mapped by 3AI across four pilot areas

PCT	Description	Biometric Vegetation Type	AG-ID	Keith Form	Keith Class
Royal Camp SF and Carwong SF					
1939	1939 - Swamp Box - Forest Red Gum - Broad-leaved Paperbark swamp forest of sandy alluvial back swamps in the lower Clarence and Richmond River valleys, South Eastern Queensland Bioregion and NSW North Coast Bioregion	NR389	700-493	Forested Wetlands	Coastal Swamp Forests
2156	2156 - Pink Bloodwood - Forest Red Gum - Thick-leaved Mahogany forest at low to mid altitudes between Chaelundi and Toonumbar, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR611	1000-1103	Dry Sclerophyll Forests	Clarence Dry Sclerophyll Forests
2157	2157 - Forest Red Gum - Broad-leaved Paperbark - Swamp Box grass/herb open forest in gently undulating areas of the lower Clarence and Richmond River valleys, South Eastern Queensland Bioregion and NSW North Coast Bioregion	NR612	1000-1107	Dry Sclerophyll Forests	Clarence Dry Sclerophyll Forests
2158	2158 - Grey Ironbark - Broad-leaved Spotted Gum shrub/grass open forest of the Clarence and lower Richmond River valleys, South Eastern Queensland Bioregion and NSW North Coast Bioregion	NR613	1000-1106	Dry Sclerophyll Forests	Clarence Dry Sclerophyll Forests
2171	2171 - Tallowwood Small-fruited Grey Gum - Forest Oak dry open forest, South Eastern Queensland Bioregion and NSW North Coast Bioregion	NR626	1000-1071	Wet Sclerophyll Forests	Northern Hinterland Wet Sclerophyll Forests
2188	2188 - Brush Box - Turpentine - Spotted Gum shrub/grass tall open forest of the escarpment foothills, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR643	1500-939	Wet Sclerophyll Forests	North Coast Wet Sclerophyll Forests
2229	2229 - Turpentine - Brush Box - Flooded Gum - Blackbutt shrubby moist forest of sub-coastal lowlands, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR684	1500-929	Wet Sclerophyll Forests	North Coast Wet Sclerophyll Forests
2243	2243 - Grey Box - Forest Red Gum grassy open forest on hills of the mid to upper Clarence and Richmond River valleys, South Eastern Queensland Bioregion and NSW North Coast Bioregion	NR698	1000-1104	Dry Sclerophyll Forests	Clarence Dry Sclerophyll Forests

PCT	Description	BVT	AG-ID	Keith Formation	Keith Class
Clouds Creek SF					
1948	1948 - River Oak grassy open forest along larger rivers, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR398	700-222	Forested Wetlands	Eastern Riverine Forests
2065	2065 - Green-leaved Rose-walnut - Sassafras - Black Booyong - Yellow Carabeen tall closed forest on sediments and metasediments of near coastal hills and escarpments, South Eastern Queensland Bioregion and NSW North Coast Bioregion	NR520	1000-1586	Rainforests	Subtropical Rainforests
2084	2084 - Brush Box - Grey Myrtle - Water Gum dry rainforests of poorer soils of gorges and river valleys, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR539	75-23	Rainforests	Dry Rainforests
2085	2085 - Grey Myrtle - Brush Box dry rainforest on metasediments and lower nutrient volcanics, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR540	700-431	Rainforests	Dry Rainforests
2125	2125 - Cabbage Gum - Broad Leaved Apple open forest of the eastern escarpment, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR580	1000-1109	Grassy Woodlands	Coastal Valley Grassy Woodlands
2140	2140 - Tallowwood - New England Blackbutt grassy open forest of plateau areas, New England Tablelands Bioregion and NSW North Coast Bioregion	NR595	0	Dry Sclerophyll Forests	Northern Gorge Dry Sclerophyll Forests
2160	2160 - Blackbutt - Red Mahogany - Bloodwood dry open forest on infertile sandy soils of low coastal rises and hills, NSW North Coast Bioregion, South Eastern Queensland Bioregion	NR615	1000-1448	Dry Sclerophyll Forests	North Coast Dry Sclerophyll Forests
2226	2226 - Tallowwood-Blackbutt moist shrubby tall open forest of the hinterland ranges of the Mid North Coast, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR681	1500-923	Wet Sclerophyll Forests	North Coast Wet Sclerophyll Forests
2227	2227 - Brush Box - Tallowwood - Sydney Blue Gum shrubby wet open forest of coastal hills and escarpment ranges, NSW North Coast Bioregion and the South Eastern Queensland Bioregion	NR682	1500-933	Wet Sclerophyll Forests	North Coast Wet Sclerophyll Forests

2228	2228 - Brush Box - Tallowwood Sydney Blue Gum moist shrubby open forest of the hinterland ranges, NSW North Coast Bioregion and the South Eastern Queensland Bioregion	NR683	1500-964	Wet Sclerophyll Forests	North Coast Wet Sclerophyll Forests
2231	2231 - New England Blackbutt-Tallowwood-Forest Maple moist shrubby tall open forest of the northern escarpment ranges, New England Tablelands Bioregion and NSW North Coast	NR686	700-420	Wet Sclerophyll Forests	Northern Escarpment Wet Sclerophyll Forests
2239	2239 - New England Blackbutt grassy open forest on well-drained soils on the escarpment, New England Tablelands Bioregion and NSW North Coast Bioregion	NR694/NR211/NR224/NR233	1000-1146	Wet Sclerophyll Forests	Northern Tableland Wet Sclerophyll Forests

PCT	Description	BVT	AG-ID	Keith Formation	Keith Class
Maria River SF					
2160	2160 - Blackbutt - Red Mahogany - Bloodwood dry open forest on infertile sandy soils of low coastal rises and hills, NSW North Coast Bioregion, South Eastern Queensland Bioregion	NR615	1000-1448	Dry Sclerophyll Forests	North Coast Dry Sclerophyll Forests
2226	2226 - Tallowwood-Blackbutt moist shrubby tall open forest of the hinterland ranges of the Mid North Coast, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR681	1500-923	Wet Sclerophyll Forests	North Coast Wet Sclerophyll Forests
2171	2171 - Tallowwood Small-fruited Grey Gum - Forest Oak dry open forest, South Eastern Queensland Bioregion and NSW North Coast Bioregion	NR626	1000-1071	Wet Sclerophyll Forests	Northern Hinterland Wet Sclerophyll Forests
2229	2229 - Turpentine - Brush Box - Flooded Gum - Blackbutt shrubby moist forest of sub-coastal lowlands, NSW North Coast Bioregion and South Eastern Queensland Bioregion	NR684	1500-929	Wet Sclerophyll Forests	North Coast Wet Sclerophyll Forests
1943	1943 - Forest Red Gum - Grey Ironbark - Willow Bottlebrush - paperbark shrubby open forest on poorly drained sites in the Port Macquarie area, NSW North Coast Bioregion	NR393	700-57	Forested Wetlands	Coastal Floodplain Wetlands

2117	2117 - Scribbly Gum - bloodwood heathy open forest on poorly drained sandy soils, South Eastern Queensland Bioregion and north-east parts of the NSW North Coast Bioregion	NR572	999-705	Dry Sclerophyll Forests	Coastal Dune Dry Sclerophyll Forests
2173	2173 - Spotted Gum Grey Ironbark Thick-leaved Mahogany Small fruited Grey Gum dry grassy open forest of the Macleay valley hinterland, NSW North Coast Bioregion	NR628	1500-131 999-719	Dry Sclerophyll Forests	Hunter-Macleay Dry Sclerophyll Forests
2174	2174 - Tallowwood - Thick-leaved mahogany - Small-fruited Grey Gum - Grey Ironbark grassy open forest on shallow sedimentary soils, NSW North Coast Bioregion and South Eastern Queensland	NR629	1500-124	Wet Sclerophyll Forests	Northern Hinterland Wet Sclerophyll Forests
2194	2194 - Turpentine - Blackbutt - Tallowwood dry shrubby open forest on sediments or granites of coastal foothills, NSW North Coast Bioregion and South Eastern Queensland	NR649	1500-925	Wet Sclerophyll Forests	North Coast Wet Sclerophyll Forests
2248	2248 - Pink Bloodwood - Red Mahogany - Swamp Box shrub/grass open forest at low altitudes, South Eastern Queensland Bioregion and northern NSW North Coast Bioregion	NR703	1000-1449	Dry Sclerophyll Forests	Clarence Dry Sclerophyll Forests