RICHMOND VALLEY KOALA HABITAT ATLAS

Australian Koala Foundation

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for

Richmond Valley Council

Final report and map prepared by

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CONTENTS

Appendices

List of Figures

List of Tables

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EXECUTIVE SUMMARY

The Australian Koala Foundation (AKF) conducted an assessment of tree species preferences and other aspects of habitat use by Koalas in the then Richmond River Local Government Area (LGA) between June, 1996 and March, 1997. A total of 4,181 trees comprised of 1,915 eucalypts and 2,259 non-eucalypts from 128 independent field sites were assessed during the study.

Tree species preferences were determined by comparative analysis of the summed proportional strike rates for 34 of the 61 tree species beneath which Koala faecal pellets were recorded according to their occurrence on each of the main geology units recognised for the purposes of the study. The results have established that four *Eucalyptus* species - Forest Red Gum *E. tereticornis,* Tallowwood *E. microcorys* Swamp Mahogany *E. robusta* and Red Mahogany *E. resinifera* (where it occurs on Coal Measures substrates) function as a primary food resource for Koalas in the study area. Levels of utilisation of *E. tereticornis* appear to be substrate dependent, with lower utilisation on Sandstone substrates. A further three species - Grey Gum *E. propinqua* and Red Mahogany *E. resinifera* (on other than Coal Measures) and Grey Ironbark *E.siderophloia* (on Coal Measures) qualify as a secondary food resource. The occurrence of these primary and secondary *Eucalyptus* species appear to be the major limiting factors affecting the distribution, abundance and autecology of Koalas inhabiting the study area.

A Koala Habitat Atlas (KHA) was derived from vegetation mapping data completed by Ecograph Pty Ltd and supplied by Council to the AKF in 2006. The KHA identified a total of 24,856 hectares of Primary Koala Habitat (12.5% of the overall study area); 4,615 hectares of Secondary Koala Habitat Class ‘A’ (2.3% of the study area); 18,237 hectares of Secondary Koala Habitat Class ‘B’ (9.2% of the study area): 29,344 hectares of Secondary Koala Habitat Class ‘C’ (14.7% of the study area) and 324 hectares of Marginal/Supplementary Koala Habitat (0.2 % of the study area). Added together, these categories of Koala habitat constitute a total area of 77,376 ha or approximately 38.9% of the 199,135 hectare mapped area. A further 194 ha of ‘Unknown’ Koala Habitat were also identified.

Notwithstanding the statutory protection afforded the Koala by the *National Parks and Wildlife Act 1974*, *State Environmental Planning Policy No. 44 (Koala Habitat Protection)* and the *Threatened Species Conservation Act 1995,* the long term conservation and management of Koala populations inhabiting the study area is largely in the hands of Local Government and the community. Threats to the continued survival of the Koala population in the study area include bushfire, loss of habitat for agriculture and residential development, predation by domestic and feral animals, and mortalities brought about by motor vehicles. These issues in turn exacerbate the potential for otherwise benign, stress-dependent pathogens such as *Chlamydia* spp. to further contribute to population decline.

In order to address these issues a number of measures are recommended for adoption. These recommendations include an immediate moratorium on further destruction or modification of Primary and Secondary Koala Habitats, initiation of a community-based Koala survey to assist in locating extant populations and raising awareness within the community, and legal sureties to enforce any Tree Preservation Orders and Covenants. Reviews of the existing Local Environmental Plan and Development Control Plans relating to current and proposed residential developments in the study area are also advocated, as is the preparation of a Shire-wide Koala Plan of Management in accordance with SEPP No. 44.

1 Introduction

1.1 Study Objectives

The specific objectives of this study included the following:

a) identify Koala food tree species within the former Richmond River LGA;

b) compile a vegetation map of the LGA to an appropriate community level;

c) identify significant areas of Koala habitat within the LGA;

d) develop an understanding with regard to the likely distribution and conservation status of Koala populations in the LGA;

e) provide a list of interim recommendations designed to assist landholders, government agencies, community groups, Richmond Valley Shire Council and other interested parties with long term conservation strategies to address the survival of Koala populations within the LGA.

1.2 The Study Area

This report covers the former Richmond River Local Government Area (LGA) on the far north coast of New South Wales. At the time of the study the LGA covered an area of approximately 241,502 hectares within latitudes 28^0 43' S and 29^0 21' S and longitudes 152^0 41' E and 153^0 29' E. The study area meets the coast from just to the south of Ballina in the north to near Yamba on the Clarence River in the south. To the west, the LGA takes in the foothills of the Great Dividing Range to an elevation of approximately 650 meters in addition to a significant portion of the Richmond River floodplain. Significant land use activities in the LGA include beef cattle production, dairying, sugar cane and tea-tree farming, small cropping, fishing and forestry activities. The LGA then incorporated all or part of 25 State Forests as well as a number of Flora Reserves, National Parks and Nature Reserves.

The geomorphology of the LGA consists of three major units. Lower elevations associated with the Richmond River floodplain are derived from Quaternary alluvial, estuarine and beach sand deposits. In the north and northwest, ranges associated with Cretaceous and Jurassic sandstones and shales have been overlain by Tertiary basalt flows associated with Lamington Volcanics. In the far west and south, older Triassic-Jurassic sandstones and shales form the upland units, for example the low near-coastal Richmond Range.

2 Background

2.1 Koala Biology and Ecology

Koalas are the largest arboreal marsupial occurring over a wide but fragmented geographical range in eastern and south-eastern Australia.Koalas feed mainly on the leaves of trees from a small number of species of the genus *Eucalyptus* (Hindell *et al* 1985) which provide a high fibre, low-protein diet (Ellis *et al* 1995). Within a particular area, only a few *Eucalyptus* species will be preferentially utilised while a variety of other species, including some non-eucalypts, appear to be utilised opportunistically for feeding or other behavioural purposes (Hindell & Lee 1991; Phillips 1990; Phillips submitted). Edaphic characteristics are also considered to influence the suitability of several important browse species (Cork & Braithwaite 1996; Phillips & Callaghan submitted). Numerous studies have suggested that Koalas need to feed frequently, cannot store excess energy as fat, and rely on a low metabolic rate and behavioural traits such as sleeping and resting to conserve energy (references cited in Cork *et al* 2000).Koalas usually feed for two to four hours per day, predominately in the early evening (Hindell *et al* 1985). It is likely that Koalas observed in a particular tree in the daytime will also feed on that tree during the night, although they may subsequently move to a different tree to continue feeding (Hindell *et al* 1985). Ellis (1995) suggested that in drier climates Koalas also feed in the morning to obtain extra moisture from dew-laden leaves. There is evidence that Koalas move into wetter areas such as drainage lines in times of drought, these animals subsequently have higher survival rates compared to Koalas unable to relocate to these areas because of occupancy by dominant resident Koalas (Gordon *et al* 1988).

Koalas are sexually dimorphic with males larger than females (McLean & Handasyde 2006) and are significantly larger in Victoria than Queensland, with a weight range of from 6.5-11.8 kg (males) and 5.1-7.9 kg (females).

Females first breed at about two years of age when body weight reaches ~6 kg (McLean & Handasyde 2006), and thereafter usually raise one young per year. Males become fully mature approximately a year after females (Gall 1980). Sex ratios in Koala colonies are unbalanced, the species is polygamous with a dominant "alpha" male mating with several females (Gall 1980). However, DNA profiling has been used to throw some doubt on the accepted paradigm of the "socially stable breeding aggregation", Ellis *et al* (2002b) found that resident (i.e. alpha) and transient males sired about equal numbers of offspring. Male Koalas may live up to about 10 years in the wild, with females living to about 12 years (Augustine 1998).

Between 20-36 months of age young Koalas disperse from their natal home ranges (about 20% of the total population), a significant proportion of which are males (Dique *et al* 2003a). Dispersal occurs just prior to and during the early part of the breeding season, which in Victoria lasts from October to March with a peak from November to January (McLean & Handasyde 2006), similar to south-east Queensland (Dique *et al* 2003a). Dispersal distances vary from 0.3 to 10.6 km with an average of 3.5 km (Gall 1980, Dique *et al* 2003a).

Koala breeding dynamics are known to be affected by the bacterial disease *Chlamydia* which may infect the reproductive tract of females, reducing the breeding rate to two years out of three in affected populations (McLean & Handasyde 2006). In Victoria most Koala populations carry *Chlamydia* (McLean & Handasyde 2006). While fecundity of individual females may be affected by *Chlamydia,* the disease does not seem to have an effect on the persistence of specific Koala populations (Augustine 1998). However, other researchers suggest that, where other limiting factors such as drought and habitat loss operate, the presence of *Chlamydia* increases population stress (Weigler *et al* 1988, Phillips 2000).

2.2 Koala tree use

Koalas generally favour habitats on soils with higher fertility and moisture availability (Lunney *et al* 2000). Near Campbelltown in NSW Koalas show a distinct preference for *E. punctata* (Grey Gum) and *E. agglomerata* (Blue-leaved Stringybark) when these species grow on shale-derived soils rather than on sandstone-derived soils (Phillips & Callaghan 2000). Soil fertility requirements have been quantified for some arboreal mammals living in eucalypts, for example the Greater Glider, *Petauroides volans*, is found where soils have phosphorus levels of 200-1400 ppm, and in one survey no arboreal animals were observed where soil phosphorus levels were below 50 ppm (Braithwaite 1996). Analysis of leaves offered to captive Koalas showed that preferred browse contained a range of 0.08-0.42% phosphorus and 0.30-2.06% potassium (Ullrey 1981). Higher foliar nutrient appears to be the major determinant of arboreal species richness and density in the Eden area of NSW (Braithwaite *et al* 1983). Foliar levels of nitrogen, potassium, and phosphorous were highly correlated, and highly correlated with levels of potassium and phosphorous in the soil (Braithwaite *et al* 1983). Koalas tend to prefer younger foliage which contains more nitrogen (Hindell *et al* 1985), less fibre and more moisture and sugars with a resultant increase in digestibility compared to mature foliage (Moore *et al* 2004b). During drought conditions trees will produce less new foliage and, as the leaves age, nitrogen content of foliage is reduced and may impose severe restrictions on the ability of Koalas to satisfy their nutritional needs (deGrabriele 1981). Captive Koalas appear to reject foliage when crude protein levels (highly correlated with nitrogen content) fall below about 10% for four species found in northern Victoria*, E. camaldulensis* (River Red Gum), *E. leucoxylon* (Yellow Gum), *E. sideroxylon* (Red Ironbark) and *E. polyanthemos* subspecies *vestita* (Red Box) (Ullrey 1981). It was concluded that, because of the great range in the level of leaf constituents both within and between species, dietary requirements over the long-term could be best met by offering a wide assortment of food choices (Ullrey 1981). The crude protein threshold of 10% was confirmed in wild Koalas by Ellis (1995).

Published studies on why Koalas prefer certain eucalypts in certain areas have sometimes focussed on the role of nutrients as food attractants contrasted with the role of toxic chemicals as feeding deterrents (Cork *et al* 2000). It is thought that where eucalypts grow in nutrient-rich areas, more of the tree energy and nutrient budgets can be directed towards production of extra foliage rather than the production of "anti-foodants" such as terpenes and some phenolic compounds which discourage consumption of foliage by arboreal mammals (Lawler *et al* 1998). Individual trees of the same species may have highly variable levels of anti-foodant compounds, Koalas actively avoid eating leaves from these individuals even though they might be preferred food trees (Lawler *et al* 1998). Koalas fed *E. melliodora* (Yellow Box) reduced their intake by half when the concentration of the phenolic compound sideroxylonal was increased to 45 mg/g (Moore *et al* 2005). In an earlier study, Koalas used larger trees with lower levels of anti-foodants (Moore *et al* 2004a) and it seems that even adjacent trees may have differing levels of anti-foodants (Moore *et al* 2004b).

Munks *et al* (1996) in a study in semi-arid north Queensland (mean annual rainfall 492 mm) found a significant positive relationship between leaf water concentration and the occurrence of Koalas. This particular study also found that Koala faecal pellet counts were at least an order of magnitude (i.e. 10 times) higher in close proximity to watercourses (Munks *et al* 1996). Additionally, faecal pellet counts increased as species richness and total basal area increased independent of watercourse proximity (Munks *et al* 1996). A mixture of old and fresh pellets was found near watercourses, whereas only older pellets were found on slopes and rises away from watercourses, suggesting that use of these areas was in summer months by dispersing sub-adult males (Munks *et al* 1996). Munks *et al* (1996) observed that sub-optimal habitats surrounding preferred habitats were important to prevent overcrowding of optimal habitats and enable normal dispersal and recruitment social behaviour mechanisms to operate.

In the arid Queensland mulgalands, Koalas use a variety of habitats including riverine, floodplain, plains and residual hills. Riverine environments had the highest percentage of trees with faecal pellets under them (47.6%), the dry residual hills had the second-highest percentage (28.6%), floodplains and plains had fewer pellets (9.5% and 14.3% of trees respectively) (Sullivan *et al* 2003).

Studies in the Brisbane Ranges of Victoria found that within their home ranges Koalas repeatedly favour some trees and actively avoid others, including trees of the same species (Hindell & Lee 1987). Results from radio-tracking studies undertaken in the drier Blair Athol area of central Queensland suggest that Koalas in these hotter, drier regions utilise a very small number of roosting trees during the day for shelter (Ellis *et al* 2002). Trees used for roosting were observed to correspond to food trees on 68% of occasions, with the study concluding that day-time roosting trees were not necessarily a good indicator of food tree preferences, especially in areas with different vegetation communities and tree species available within a Koala's home range (Ellis *et al* 2002). These findings appeared to differ from Victorian studies where multiple tree use was more common in areas with much higher Koala density (Ellis 2002a). Ellis (2002a) concluded that, over time, Koalas would use most of the trees available within their home range, and that assertions about the use of specific trees for social behaviour had little support.

In the same area of central Queensland, Ellis (1995) found a distinct variation in seasonal tree use, with winter food trees providing more energy, and summer food trees providing more moisture, a finding backed by laboratory analysis of collected leaves. Seasonal tree use is also prevalent in Victoria, with Koalas feeding on *E. ovata* (Swamp Gum) in winter and *E. obliqua* (Messmate) in summer when this species had abundant new growth (Martin 1985). In south-east Queensland, female access to *E. tereticornis* (Forest Red Gum) appeared to be an important requirement during the breeding season, at other times of the year they preferred *E. crebra* (Narrow-leaved Ironbark), in part due to males denying access to *E. tereticornis* (White 1999). Male dominance of preferred trees also occurs on the North Coast of NSW (AKF unpub. data). It appears that occupation of preferred trees by male Koalas is an important dynamic in the configuration of breeding Koala populations.

Koalas demonstrate a preference for larger trees (Phillips & Callaghan 2000, Lunney *et al* 2000, Santamaria *et al* 2005, Hindell & Lee, 1987), this preference could be due to a number of factors including a larger crown (West *et al* 1991). Preference for larger trees is independent of sex and season (Hindell & Lee 1987, White 1999, Santamaria *et al* 2005) and in some cases Koalas exhibit a seasonal preference for certain tree species within their home range, in other cases they show no such preference (Hindell & Lee 1987). Koalas tend to be sedentary, with the exception of juvenile males dispersing from their maternal range. It would therefore be advantageous for Koalas to locate their home ranges in areas containing trees used preferentially in different seasons (Hindell & Lee 1987). Fidelity to the home range area by constituent Koalas is long term and can extend over many years (Lee & Martin 1988; Mitchell 1990; Mitchell & Martin 1990).

2.3 Koala Home Range Size

Radio tracking of collared Koalas is the favoured method of establishing home-ranging behaviour of Koalas (White 1999, Ellis *et al* 2002, Dique *et al* 2004, AKF unpub. data). Determination of the size of Koala home ranges is problematic owing to the patchy nature of habitat use and unsymmetrical shape of home ranges (Hindell & Lee 1988). However, harmonic mean analysis overcomes these issues by defining the main centres of activity within a home range (Hindell & Lee 1988).

Analyses using the above technique have shown that male Koala home ranges tended to have more than one centre of activity and an irregular shape, whereas female home ranges tended to be circular with a single centre of activity (Hindell & Lee 1988). Home range size may change between breeding and non-breeding seasons with the proportion of overlap between male-female home ranges tending to increase, and male-male overlap tending to decrease (Ellis *et al* 2002). The shape of male Koalas' home ranges may be due to the largely polygamous nature of Koala breeding units, an alpha male will attempt to encompass the home range of, say, 3-4 females whose home ranges overlap only slightly, however, this hypothesis was untested by comparing the centres of activity between males and females (Hindell & Lee 1988).

In a similar study undertaken by the AKF on the NSW North Coast, 10 Koalas (4 males and 6 females) were radiotracked with home ranges calculated using harmonic means (AKF unpub. data). Home range sizes varied with the highest figure belonging to the group's alpha male who occupied a home range with a high percentage of open farmland, and the lowest figure belonging to a female in very high-quality habitat (AKF unpub. data). Appendix I shows an aerial photograph the arrangement of Koala home ranges ascertained in this study.

In the Blair Athol area Koalas had well-defined home ranges averaging 135 ha in size for males and 101 ha for females, however the smallest home range was 5.4 ha and the largest 296 ha (both males) (Ellis *et al* 2002). In rural south-east Queensland, home ranges varied from 5.3 to 91.4 ha, with approximately 25% overlap (White 1999).

Sullivan (2004) developed a "faecal standing crop" method whereby Koala densities were calculated based on number of pellets counted and average daily deposition rate. This method compared favourably to a direct visual count method which estimated Koala densities at 0.32-0.45 Koalas/ha in riverine habitats in the Queensland mulgalands (Sullivan 2004).

Other studies have found large variation in the density of Koalas (a converse measure of home range size), for example as high as 8.6-8.9 Koalas/ha in habitat fragments and as low as 0.7-1.6/ha elsewhere in Victoria (Meltzer *et al* 2000). In NSW, densities were measured at 0.006/ha at Eden and 4-8/ha in north-east NSW, and in Queensland from 0.01/ha in central Queensland to 1-3/ha in south-east Queensland (Meltzer *et al* 2000). Another study in south-east Queensland found mean densities varied from 0.02 to 1.26 Koalas/ha (Dique *et al* 2004). A pioneering study at Tucki Tucki Reserve on the North Coast of NSW found a density of nearly 7 Koalas/ha in high-quality habitat with about 30 trees for each Koala available, but only about 1 Koala/ha in adjacent similar-quality habitat (Gall 1980). On French Island in Victoria Koalas had from 18 to 40 trees available in each home range (Mitchell 1990a).

Table 1 summarises home range information from published papers.Koala densities from other sources have been converted to home range equivalents using 20% overlap between home ranges (Table 2). The great disparity in home range size is likely due to a combination of factors including variation in soil fertility, rainfall, historical disturbance (drought, fire, past hunting), habitat fragmentation, and the methodologies employed in each study. On French Island home ranges tended to be bigger with increasing tree density, an indication that Koalas prefer bigger trees further apart than smaller trees closer together (Mitchell 1990a).

State	Area	Male			Female			Overlap %	Source
		Minimum	Max.	Mean	Minimum	Max.	Mean		
VIC	Brisbane Ranges	2.13	4.14	3.14	1.22	2.08	2.94		Hindell & Lee 1988
VIC	French Island			1.7			1.18		Mitchell 1990
NSW	Tweed Coast	10.78	42.78	20.3	1.84	16.28	8.82	20	AKF unpub. Data
QLD	Blair Athol	5.4	296	135			101		Ellis *et al* 2002
QLD	south-east	(5.3)	(91.4)	34.4	(5.3)	(91.4)	15	25	White 1999

Table 1: Koala home range sizes from previous research. For White (1999) no distinction was made between male and female maximum/minimum home range size.

State	Location	Koalas/ha		Home range (20% overlap)		Source
		Min	Max	Min	Max	
VIC	fragmented	8.6	8.9	0.1	0.09	Meltzer *et al* 2000
VIC	other	0.7	1.6	1.14	0.5	Meltzer *et al* 2000
NSW	Eden	0.006			133.3	Meltzer *et al* 2000
NSW	north-east	4	8	0.1	0.2	Meltzer *et al* 2000
NSW	Tucki Tucki	1	7	0.11	0.8	Gall 1980
QLD	Mulgalands	0.32	.45	1.8	2.5	Sullivan 2004
QLD	south-east	0.02	1.26	0.6	40	Dique *et al* 2004
QLD	central	0.01			80	Meltzer *et al* 2000
QLD	south-east	1	3	0.06	0.8	Meltzer *et al* 2000

Table 2: Density estimates from previous research. Densities are converted to home range sizes, allowing for a 20% overlap between home ranges (White 1999 and AKF unpub. data).

Radio tracking also provides data on the distances Koalas move over a defined period, White (1999) found that, for radio-tracking records at least 30 days apart, 50% of movements were between 200 and 500 m, a further 35% were between 500 m and 1 km, and the rest were under 5 km. For records three days apart, 20% were in the range 2 - 5 km (White 1999), indicating that Koalas often roam considerable distances from their home ranges before returning (White 1999).

Hindell and Lee (1987) also found that as well as certain large trees being preferentially used, use of these trees was not exclusively by one animal. Larger trees may offer several advantages to Koalas, including increased shelter and food availability because of a larger canopy (Hindell & Lee 1987), and greater access to water and nutrients because of a deeper root system (Phillips & Callaghan 2000). A recent study at St Bees Island off the coast of central Queensland found a marked difference in the use of trees, with closed-canopy trees used as shelter during the day, and open-canopy trees, particularly *Eucalyptus tereticornis* (Forest Red Gum), used for feeding at night (Pfeiffer *et al* 2005). 91.4% of nocturnal Koala observations were in *E. tereticornis*, with 20.4% of daytime observations in this species (Pfeiffer *et al* 2005). Koalas exposed to full sun in this humid environment appeared stressed, with laboured breathing evident (Pfeiffer *et al* 2005). Unpublished research by NSW State Forests reports "…dense foliage of white cypress pines and rough-barked apples were frequently used by Koalas as daytime resting sites"…"to cope with the extremes of regular high summer temperatures" (DPI 1999)

2.4 Koala faecal pellets

Faecal pellet surveys have been used by many Koala researchers (Lunney *et al* 1998, Lunney *et al* 2000, Phillips & Callaghan 2000, Phillips *et al* 2000, Sullivan *et al* 2002). The primary advantage of this type of survey arises from the fact that faecal pellets persist long after a Koala has left the area (Lunney *et al* 2000) and are distinctive in shape and size compared to faecal pellets of other animals (McAlpine *et al* 2006b).

As Koala faecal pellets are a fundamental part of this study it is useful to know something about the spatial and temporal aspects of faecal pellet deposition. A study of Queensland Koalas found that most pellets are deposited between 6 p.m. and midnight when Koalas were most active, and rarely when Koalas were resting during the day (Ellis *et al* 1998). A disproportionately high percentage of pellets were found within one metre of tree trunks, however this amount represented only 9% of total daily production (Ellis *et al* 1998). The proportion of pellets within one metre of the trunk may be low, however this result does not necessarily have any effect on the presence or absence of single pellets (AKF unpub. data). Free-ranging Koalas will produce an average of 150 faecal pellets/day (Sullivan *et al* 2004).

Assessing the age of faecal pellets can be achieved by examination of physical changes in the pellet, for example presence or absence of surface patina, colour change from olive-brown to greyish, loss of eucalyptus odor with age, and bleaching of leaf cuticle within the pellet. (Sullivan *et al* 2002). In the arid and semi-arid environments of the Queensland mulgalands, pellets aged with these criteria were classed as fresh (0-28 days) or old (14-28 days) (Sullivan *et al* 2002). The rate of ageing is primarily affected by rainfall and substrate moisture (White 1995) with breakdown occurring more rapidly in summer than winter (Sullivan *et al* 2002). In more humid coastal climates (Port Stephens, NSW) pellets begin to decay after 6 weeks and persist for up to 6 months (Lunney *et al* 1998) or 24 months in the Eden (NSW) area (Jurskis & Potter 1997).

2.5 Landscape Ecology

Landscape structure can be conveniently divided into three fundamental elements: patches, corridors, and the matrix. A patch is a relatively homogenous area of vegetation that differs from its surroundings, patches > 200 m apart can be considered isolated (McAlpine *et al* 2006a). A corridor is a linear strip of habitat different to its surroundings, while the matrix is the most extensive and most connected landscape element in which patches and corridors are embedded, for example cleared land in farming areas is classed as matrix (McAlpine *et al* 2006a).

Habitat fragmentation may be defined as the successive subdivision of habitat into smaller, more numerous and more isolated patches (McAlpine *et al* 2006a). Fragmentation is a major issue for Koala conservation in light of the fact that the low-energy, low-nutrient diet provided by eucalypt leaves provides reduced scope (because of increasing energy cost) for Koalas to travel across open ground between habitat fragments (White 1999, DSE 2004).

Patches can be considered as coarse-grained if the patch is bigger than a Koala's home range, and fine-grained if the home range consists of two or more patches (White 1999). Koalas inhabiting home ranges composed of more than one patch must necessarily cross open ground to access patches. In urban areas dogs and cars increase the danger of travel between patches (White 1999). White (1999) found that Koalas often use isolated paddock trees and make frequent long-range movements (> 2 km) across open ground, and concluded that Koalas were not reliant on continuously-vegetated corridor systems which were absent from the study area (White 1999).

However, recent studies (McAlpine *et al* 2004, Rhodes *et al* 2006) have demonstrated that large patches of habitat with effective connections are essential for the long-term maintenance of Koala populations in three geographically dispersed areas in eastern Australia (Noosa, Port Stephens and Ballarat).

Corridors may be used by resident adult Koalas with stable home ranges as well as by dispersing animals. A study on the Strathbogie plateau in Victoria found densities of Koalas to be similar (8-9/ha) in both larger forest patches and in corridors, use of which was independent of the distance to forest patches (Downes *et al* 1997).

Habitat patches are subject to edge effects including weed invasion and wind dessication. Patch shape is an important consideration: linear patches, including corridors, have a relatively longer edge than circular patches and so are more susceptible to edge effects (McAlpine *et al* 2006a). It has been suggested that larger circular patches some distance apart act as “stepping stones” and, in revegetation projects, it is better to increase the size of these patches rather than attempt to link them with a narrow corridor (McAlpine *et al* 2006a).

Secondary and supplementary habitats provide a crucial role in maintaining Koala populations in several different ways, particularly when they are in close proximity to preferred habitat. These habitats provide a buffer by ensuring that incompatible land use does not occur on land immediately adjacent to preferred habitat and can help protect preferred habitat from edge effects and nutrient impacts (McAlpine *et al* 2006a). Secondary habitats also provide for the extension of significant Koala activity of a breeding group by providing additional habitat, and habitat for sub-dominant Koalas unable to establish home ranges in richer habitat (McAlpine *et al* 2006a). Secondary and supplementary habitats also provide vegetated links between areas of preferred habitat, enabling safer dispersal and recruitment of sub-adult Koalas (McAlpine *et al* 2006a).

2.6 Historical factors

Higher-quality Koala habitat generally occurs on soils mostly cleared for agriculture and pasture, and increasingly for urban development, especially in coastal areas (Lunney *et al* 2000). The loss of better-quality valley habitats supporting high-density Koala populations has meant that remaining Koalas persist mainly in poorer-quality hilly habitats with a lower “carrying capacity”, that is, at much lower densities (Lunney & Leary 1988). Remaining habitats are predominately in privately-held forests and are poorly represented in reserves (Braithwaite 1996).

Koalas were previously widespread in eastern Australia and an intensive hunting industry developed however by 1910 the industry had collapsed due to a shortage of

Koalas (Meltzer *et al* 2000). At about the same time the large Bega Valley (NSW) Koala population crashed, an event ascribed to increased disease susceptibility as a result of nutritional stress arising from destruction of the better-quality valley habitat (Lunney & Leary (1988). Hunting, combined with drought, clearing, wildfire and disease, meant that Koalas had disappeared from most of Victoria, with possibly as few as 1000 animals remaining by 1934 (Melzer *et al* 2000).

The ability of Koala populations to apparently sustain themselves following a deleterious impact is more often a reflection of the species relative longevity than it is any other factor, a contention noted by Lunney & Moon (1993) in their recording of localised extinctions occurring up to 16 years after habitat alienation in the Coffs Harbour area for the purposes of urban expansion.

There is little doubt that broadacre clearing and wholesale destruction of Koala habitat, together with the *ad hoc* removal of trees which otherwise allow Koala populations to maintain their social stability and nutritional well being, are the most important factors contributing to declining Koala populations in many areas. The species is listed as 'Vulnerable' for the purposes of the *Threatened Species Conservation Act 1995.*

2.7 State Environment Planning Policy 44 (SEPP 44)

The Koala is protected by the *National Parks and Wildlife Act 1974* and listed as a vulnerable species under the NSW *Threatened Species Conservation Act 1995* (TSC Act). Most Koala populations in NSW now survive in fragmented and isolated habitat, with the largest populations found on the north coast and central west of the State. Ongoing threats include landclearing for agriculture and urban development, bushfire, and dogs and motor vehicles.

The TSC Act "requires that the Director-General of National Parks & Wildlife prepare a recovery plan for all species, populations and ecological communities listed as endangered or vulnerable on the Schedules of the Act".

The NSW *Environmental Planning & Assessment Act 1979* provides for the creation of environment planning instruments including state environmental planning policies

(SEPPs), regional environmental plans (REPs) and local environmental plans (LEPs). SEPP 44 (Koala Habitat Protection) was specifically created to improve the protection of the Koala by encouraging "the proper conservation and management of areas of natural vegetation that provide habitat for Koalas, to ensure permanent free-living populations over their present range and to reverse the current trend of population decline" (DECC 2003). This aim was to be achieved by identifying areas of core Koala habitat and providing for its protection by inclusion in environment protection zones. SEPP 44 "encourages a coordinated and strategic approach to Koala habitat management within Local Government Areas (LGAs) through the preparation of Comprehensive Koala Plans of Management (CKPoM). CKPoMs can be prepared for the whole of the LGA or any part of the LGA where important Koala populations and/or Koala habitat is under threat. In CKPoMs, Koala habitat is identified by community and field-based surveys and ranked in terms of its quality (for example primary, secondary and tertiary habitat)" (DECC 2003).

CKPoMs have been adopted in Campbelltown, Port Stephens and Coffs Harbour Local Government Areas (LGAs), with Kempsey Shire Council announcing its intention to proceed with a CKPoM in 2007.

Following the vulnerable listing of the Koala under the TSC ACT, the Koala Draft Recovery Plan (DRP) was released in 2003 by DECC. The DRP describes the legislation and planning instruments which are to be used to facilitate the protection and recovery of Koala populations in NSW, current conservation status in Australia ad NSW, biology and ecology including genetics, social organisation, habitat and feeding requirements, current threats to the long-term viability of Koala populations, and provides definitions of Koala habitat categories.

3 Methodology

3.1 Assessment of Habitat Utilisation by Koalas in the Study Area

Habitat utilisation parameters and the specific tree preferences of Koalas in the study area were assessed using a plot-based methodology developed for the purposes of the Koala Habitat Atlas (KHA) project (Sharp & Phillips 1997; Phillips *et al.* submitted; Phillips & Callaghan submitted, McAlpine *et al* 2006b). Plot selection in accordance with KHA methodology is primarily influenced by the need to sample the range of edaphic and floristic variables in a given study area to the fullest extent possible and to ensure that statistically-useful data sets are compiled for each of the commonly utilised tree species. To obtain a dataset for rigorous statistical analysis of tree preferences, np and n(1-p) must both be greater than 5 where n = number of trees of a particular species from SAT sites, and p = the pooled strike rate for that species from active sites (Sokal & Rohlf 1995, Lunney *et al* 2000, Phillips *et al* 2000). Additionally, each species needs to be sampled from a minimum of 7 independent sites (Phillips *et al* 2000). This latter consideration in particular inevitably leads to the introduction of some bias in site selection as sampling proceeds over the longer term.

Plot-based vegetation data collected during the course of Koala habitat assessments were also utilised to the accuracy accuracy of the vegetation mapping and to provide indicative species density values for habitat description and mapping purposes.

3.2 Site Selection

The study area was initially sub-divided into its respective geological units based on maps obtained from the Department of Mineral Resources. These areas were then overlain with 1: 25,000 vegetation and/or forest type maps, the latter supplied by State Forests of NSW. Plot localities were determined using a 50m grid based numerical overlay with independently generated random numbers. The resulting site co-ordinates were then transferred to GPS units to facilitate their location in the field. Where possible, independent replicates for each vegetation association occurring on each particular land unit were generated to facilitate the compilation of statistically useful data sets.

Statistical analyses require a minimum data set for each tree species. This consideration is dependent upon the density of a given species within each of the plots assessed and also influences the required number of plot sites. Plot sites were dispersed as widely as possible over the distribution of each vegetation association on each substrate throughout the study area. To reduce the risk of survey data being significantly influenced by edge effects, wherever possible, plots were excluded from sites adjacent to major habitat disturbances such as recent bushfire, urban development and/or major roads.

3.3 Vegetation Mapping

Accurate vegetation mapping is arguably the most critical of the data layers required for modelling purposes. Concurrently with Koala Habitat assessment, vegetation mapping to identify location and extent of vegetation communities was conducted by Robert Payne Ecological Surveys and Management. This mapping was plotted on 1:25000 topographic mapsheets, digitised using Genamap software and incorporated into the AKF GIS database along with State Forests of NSW Type 17 mapping and NPWS mapping of Broadwater and Bundjalung National Parks for subsequent spatial analyses of the SAT data. The vegetation was described structurally according to the classification of Specht (1981) and floristics on the style and standards of the New South Wales Herbarium. The common and scientific names of eucalypts followed that of Hill (1991) with the exception of the bloodwoods; Hill's (1996) revision which resulted in erection of the genus *Corymbia* was subsequently applied. At a number of locations within each of the identified vegetation communities 20m^2 quadrat based descriptions were compiled. The most commonly occurring plant species were noted within each quadrat. At the end of the investigation all commonly occurring plant species recorded within each structural type were combined to provide an overall description of each association. Where necessary, plant specimens were collected and matched against voucher specimens held at the New South Wales Herbarium.

Unfortunately the vegetation mapping process was not finalised, subsequently in 2004 Ecograph was commissioned by Richmond Valley Council to complete the vegetation mapping project. Final GIS vegetation data was supplied to AKF in 2006 in order to complete the Koala Habitat Atlas. Fifty-three of 58 vegetation classes in this dataset were comprised of native species of interest to Koala habitat modelling.

3.4 Assessment of Field Sites

Once located in the field, establishment of each 40m X 40m field site involved using a compass, measuring tape and flagging tape to designate the corners of four 20m X 20m quadrats on the basis of bearings along each of the four cardinal compass points (North, South, East and West) from a central reference point; this point served as a corner for each of the four quadrats which were then given an alphabetical designation A, B, C and D in a clockwise direction with "A" always being located in the northwestern quadrat. Alternatively, when Koala faecal pellets were opportunistically encountered in the field, the 'Spot Assessment Technique' (SAT) of Phillips and Callaghan (1995) was applied. Data from each respective quadrat or circular plot site was recorded on a specific KHA site recording form.

The aspect (in degrees) from the approximate centre of each field site was recorded and every tree that had a diameter at breast height (dbh) of 100 mm or greater was marked with flagging tape which was later removed as each tree was assessed.

Tree species were recorded using a four letter code based on the first initial of the genus name and the first three initials of the species name. For the purposes of KHA methodology a "tree" was defined as "*a live woody stem of any plant species (excepting palms, cycads, tree-ferns and grass-trees) which has a diameter at breast height (dbh) of 100 mm or greater*".

The diameter at breast height was measured and the base of each tree carefully inspected for the presence of Koala faecal pellets within a circle of 100 cm radius from any point at the base of each tree. If the tree species identity was not known it was recorded as such but still assessed using the protocol prescribed by this methodology. Leaf samples, seed capsules and/or flowers or fruits along with a general description of the tree were also collected to enable the species' taxonomic identity to be ascertained.

Faecal pellet searches were initiated with a precursory inspection of the area described above followed by a more thorough inspection of the substrate; including disturbance of leaf litter and any ground cover. Approximately two to three person minutes were devoted to the faecal pellet search at each tree. Any pellets recorded were replaced at the base of each respective tree. Where the distribution of pellets fell within the search catchments of two or more trees the above protocol was applied to the extent that the presence of any pellets within a 100 cm radius of each tree were recorded independently.

3.5 Data Analysis

To avoid biasing results where the recorded absence of faecal pellets was possibly a consequence of historical factors rather than poor Koala habitat quality *per se*, field SAT sites were categorised as either "active" or "non-active", depending on whether faecal pellets were present or absent respectively. Only "active" sites were considered for analysis purposes.

No consideration was given to the total number of Koala faecal pellets beneath a given tree, rather they were simply recorded as either present or absent. Activity levels for each plot were expressed as a percentage equivalent of the quotient derived by dividing the total number of trees (all species) which had one or more Koala faecal pellets beneath them by the total number of trees (all species).

For each tree species, a notional level of use referred to as "strike rate" was determined based on the number of individual trees of a given species which had one or more Koala faecal pellets recorded in the prescribed search area, divided by the total number of trees of that species recorded in the respective plot.

Tree species preferences and habitat utilisation considerations were determined from a pooled and comparative analysis of the results from all "active" plots. In this regard, data sets for each of the tree species growing on a particular substrate were regarded as most useful when the data set for a given species had been obtained from at least seven independent but otherwise "active" sites and when both np and $n(1-p) \geq 5$, where n = the total number of trees of that species sampled and p = the proportion of trees of that species sampled which had faecal pellets recorded within the prescribed catchment area.

All statistical analyses followed protocols and procedures detailed by Sokal and Rohlf (1995). For the primary dataset an 'Unplanned Test of the Homogeneity of Replicates' using simultaneous test procedures was used to establish maximally "significant" and maximally "insignificant" data sets, areas of non-overlap identifying those species with significantly higher and lower levels of utilisation respectively. Species which were isolated as being the subject of significantly higher levels of utilisation were thus regarded as primary food trees. A *post hoc* Test of Association (Mann-Whitney U-test) was subsequently undertaken to examine the extent to which the presence/absence of those species determined by the above process to be preferentially-utilised influenced strike rates of other species. In the absence of a primary tree species the utilisation of secondary tree species may increase as these species are targeted for their food resources.

While these species are of secondary importance to Koalas when compared to primary tree species, their retention in adequate numbers is necessary if effective conservation is to be achieved. Indeed, it can be demonstrated that such species are capable of sustaining Koala populations over the long term, albeit at lower densities (Phillips & Callaghan submitted).

The use of trees compared to their general availability can also be a useful tool to understand more about how Koalas use different species. A primary tree species will normally have a higher usage than its general availability compared to secondary species which in turn will have a higher usage than non-targeted species. For each SAT site, the number of trees of each species with pellets is divided by the total number of trees with pellets to give a measure of usage for each species. Similiarly, the number of trees of each species at each site is divided by the total number of trees at each site, giving a measure of species availability. The usage and availability values for each species at each site are subtracted and averaged to provide an overall measure of Usage versus Availability (U-A). Species utilised in proportion to their abundance will have a U-A measure of 0, trees targeted by Koalas will have a positive U-A measure and trees generally avoided by Koalas will have a negative U-A measure.

Data from all SAT sites within a study area is pooled and statistically analysed using these techniques to develop tree preferences for Koalas in a particular area (Phillips & Callaghan, submitted). The tree preferences are then ranked as primary, secondary or supplementary for use in the Koala Habitat Atlas (McAlpine *et al* 2006b). Other data collected include an estimate of pellet age, fire history and site disturbance.

The activity level (percentage of trees with pellets) at each SAT site is calculated. Phillips and Callaghan (submitted) propose three categories of Koala activity, with differences in activity level categories dependent on whether the site location is coastal/tablelands with higher rainfall or inland with rainfall <600 mm. The Richmond Valley area falls into the coastal category with medium-high Koala population density. Table 3 shows the activity levels proposed by Phillips and Callaghan (submitted) for this particular coastal category.

Activity Category	Low use	Medium (normal) use	High use
Medium-high density	<22.5%	>22.5% but <32.8%	>32.8%

Table 3: Koala site activity categories for Coastal areas (Phillips & Callaghan, submitted.)

3.6 Compilation of Attribute Layers for Modelling Purposes

The Koala Habitat Atlas (KHA) is a technique developed and used by the Australian Koala Foundation (AKF) to map and rank Koala habitat quality and has been in use since 1994. The KHA is primarily based on vegetation community mapping derived from aerial photography, with a Koala habitat ranking for each community based on the proportional abundance of identified primary, secondary and supplementary trees (McAlpine *et al* 2006b). Primary trees have a significantly higher proportion of surveyed trees with one or more Koala faecal pellets around the base compared to other tree species, secondary trees have a significantly higher proportion of faecal pellets than other trees (but less than primary trees) and supplementary trees have a lower proportion of trees with pellets compared to primary or secondary trees, but still significantly higher than trees lacking any evidence of use by Koalas (McAlpine *et al* 2006b). Additionally, other non-eucalypt trees may be used as supplementary trees, and both eucalypt and non-eucalypt trees may be used to provide shelter (McAlpine *et al* 2006b). Vegetation communities as delineated on a map can then be ranked according to the proportion of primary, secondary and supplementary trees in each community, and displayed on a map as a Koala Habitat Atlas. The different habitat classes are listed in Table 4. Primary Habitat is capable of supporting high-density Koala populations, Secondary Habitat Class ‘C’ is capable of supporting low-density populations, while Supplementary Habitat (“Marginal Habitat” in Option Two of the Draft Recovery Plan for the Koala) does not contain primary or secondary food tree species, but forms important functions as habitat buffers and linking areas.

Habitat Quality Class	Tree Rank and percentage of Overstorey			
	Primary euc. species	Primary & Secondary euc. species	Secondary euc. species	Supplementary species
Primary Habitat	>50%			Balance
Secondary Habitat Class 'A'	30<50%	or Prim. + Sec. >50%	or >50%	Balance
Secondary Habitat Class 'B'	<30%	or 30<50%	or 30<50% (Prim. trees Absent)	Balance
Secondary Habitat Class 'C'	absent	Prim. Trees absent	or <30%	Balance
Supplementary Habitat	absent	absent	absent	Balance
Mainly cleared	Scattered trees	Scattered trees	Scattered trees	Scattered trees

Table 4: Derivation of Koala habitat classes used in the AKF's Koala Habitat Atlas, one of two habitat class options utilised in the Draft Recovery Plan for the Koala (DECC 2003).

The Koala Habitat Atlas methodology, incorporating the Spot Assessment Technique, has been used by the AKF for over 10 projects in Victoria, NSW and Queensland and has been endorsed by lead conservation agencies as a suitable method to identify, map, and rank Koala habitats. (DSE 2004, NPWS 2003).

4.0 Results

4.1 Koala Habitat Utilisation in the Study Area

Data was collected on 4,181 trees at 128 sites using either 40 m by 40 m quadrats or sites using a Spot Assessment Technique (SAT) with a 30 m radius. In addition, GPS coordinates were collected at each site. (In 1996 GPS accuracy was of the order of 100 metres, three sets of coordinates were measured for each site and averaged.) Of 90 "active" sites where Koala pellets were found, data on 3,109 trees was collected Summary data is presented in Table 3 and locations of SAT sites are shown in Figure 1.

Sites	Number of sites	Eucalypts	Non-Eucalypts
Active	90	1389	1720
Inactive	38	871	201
Total	128	2260	1921

Table 5: Summary of Spot Assessment Technique site data

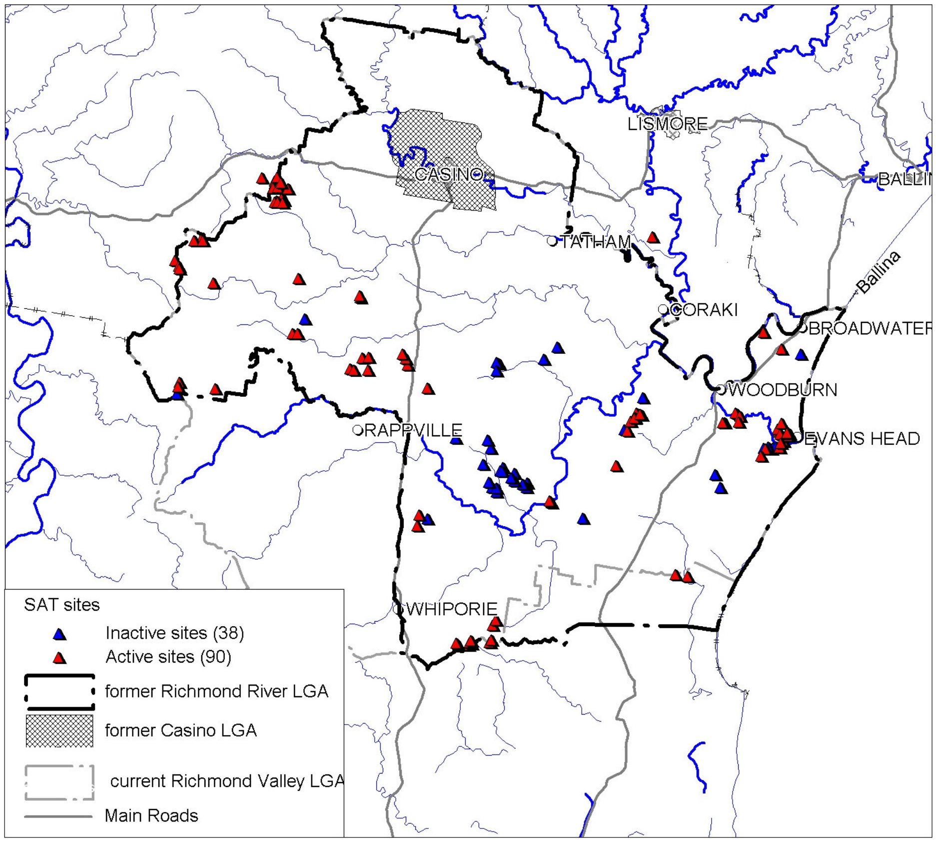

Figure 1: Location of SAT sites

Mean Activity level for active sites was classed as medium to low at 24.5 % (median 18.5%, s.d. 21.1%, 95% confidence limits). Activity levels are shown in Fig. 2.

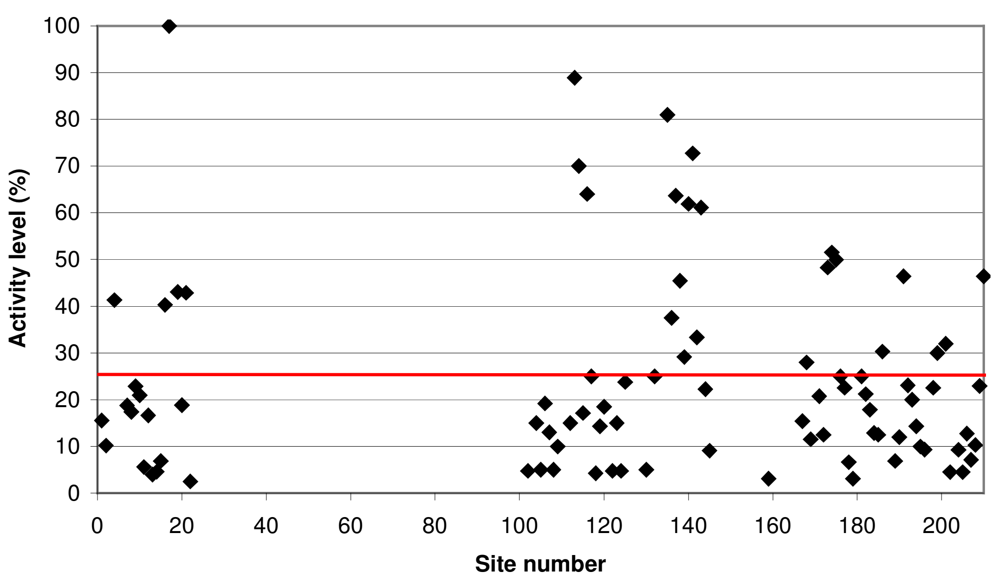

Figure 2: Activity level for each SAT site. Activity level is the percentage of trees at each site with one or more Koala faecal pellets recorded. Mean activity level = 24.5%

Pooled results from all active SAT sites are shown in Table 6, where species shown in **bold** satisfy all criteria for inclusion in a primary dataset suitable for rigorous statistical analyses, other species (with a minimum of three independent sites) form a subsidiary dataset suitable for less rigorous but nevertheless informative analyses.

Eucalypt Species	No. of sites	No. trees (n)	No. with pellets	Strike rate (p)	np	n(1-p)
Eucalyptus siderophloia	**57**	229	29	0.127	**29**	**200**
E. acmenoides	**45**	181	32	0.177	**32**	**149**
E. propinqua	**38**	249	60	0.241	**60**	**189**
E. microcorys	**36**	107	52	0.486	**52**	**55**
E. tereticornis	**33**	172	56	0.326	**56**	**116**
E. moluccana	**23**	149	27	0.181	**27**	**122**
E. pilularis	**22**	150	13	0.087	**13**	**137**
E. seeana	**19**	84	9	0.107	**9**	**75**
E. resinifera	**18**	49	21	0.429	**21**	**28**
E. tindaliae	**14**	61	14	0.230	**14**	**47**
E. robusta	**12**	227	85	0.374	**85**	**142**
E. eugenioides	**8**	24	6	0.250	**6**	**18**
E. planchoniana	**7**	56	10	0.179	**10**	**46**
E. glaucina	6	37	6	0.162	6	31
E. amplifolia	5	33	0	0.000	0	33
E. spp.	4	11	0	0.000	0	11
E. signata	4	28	2	0.071	2	26
E. grandis	3	12	0	0.000	0	12
E. fibrosa	2	13	1	0.077	1	12
E. crebra	2	22	3	0.136	3	19
E. saligna	1	10	0	0.000	0	10
E. rummeryi	1	3	0	0.000	0	3
E. carnea	1	3	0	0.000	0	3
E. bancroftii	1	5	0	0.000	0	5

Other Species	No. of sites	No. trees (n)	No. with pellets	Strike rate (p)	np	n(1-p)
Corymbia intermedia	**62**	318	34	0.107	**34**	**284**
Allocasuarina torulosa	**53**	289	30	0.104	**30**	**259**
Corymbia maculata	**50**	529	68	0.129	**68**	**461**
Lophostemon suaveolens	**34**	284	15	0.053	**15**	**269**
Melaleuca quinquenervia	**18**	95	28	0.295	**28**	**67**
Acacia aulocarpa	**14**	120	11	0.092	**11**	**109**
Syncarpia glomulifera	**13**	72	14	0.194	**14**	**58**
Corymbia gummifera	**12**	121	10	0.083	**10**	**111**
Lophostemon confertus	18	52	4	0.077	4	48
Alphitonia excelsa	17	28	1	0.036	1	27
Angophora floribunda	17	55	1	0.018	1	54
Acacia melanoxylon	10	15	3	0.200	3	12
Acacia. spp.	9	18	2	0.111	2	16
Casuarina glauca	8	32	3	0.094	3	29
Rainforest species	6	23	4	0.174	4	19
Banksia serrata	6	40	5	0.125	5	35

Callistemon salignus	5	24	6	0.250	6	18
Allocasuarina litoralis	5	35	2	0.057	2	33
Melaleuca nodosa	4	5	0	0.000	0	5
Trochocarpa laurina	3	6	1	0.167	1	5
Corymbia henryii	3	57	4	0.070	4	53
Ficus species	2	2	0	0.000	0	2
Commersonia bartramia	2	2	1	0.500	1	1
Ceratopetalum apetalum	2	6	0	0.000	0	6
Angophora subvelutina	2	11	1	0.091	1	10
Endiandra sieberi	1	6	1	0.167	1	5
Syzygium species	1	1	0	0.000	0	1
Synoum glandulosum	1	7	0	0.000	0	7
Pittosporum undulatum	1	1	0	0.000	0	1
Persoonia species	1	1	0	0.000	0	1
Duboisia myoporoides	1	3	0	0.000	0	3
Brachychiton acerifolius	1	1	0	0.000	0	1
Banskia species	1	1	0	0.000	0	1
Banksia integrifolia	1	3	0	0.000	0	3
Angophora bakeri	1	2	0	0.000	0	2
Unknown sp.	1	1	0	0.000	0	1

Table 6: Results from active field plots across all substrates in the study area. Species shown in bold satisfied sampling criteria of more than 7 sites, with np and n(1-p) both greater than 5. These species form the primary dataset. Other species from a minimum of 3 sites form a subsidiary dataset.

G-tests for Independence

There was significant heterogeneity amongst the strike rates in the entire primary data set when tested for Goodness of Fit (G_{adj} = 261.3008 (p = 0) > $X^2_{.05[20]}$) with highly significant differences between eucalypts and non-eucalypts (G_{adj} = 94.214 (p = 0) > $X^2_{.05[1]}$).

Using iterative G-tests, 3 species groups with significantly differing Koala utilisation levels were identified within the primary dataset (G_{adj} = 232.8383 (p = 0) > $X^2_{.05[2]}$). *Eucalyptus microcorys, E. resinifera, E. robusta* and *E. tereticornis* had significantly higher use by Koalas when compared to other species and can be regarded as primary tree species on this basis. The next (secondary) group of species (including some non-eucalypts) has significantly higher levels of utilisation than the third (supplementary) group (G_{adj} = 16.8665 (p = 0.0315)> $X^2_{.05[1]}$). The three groups are shown in Table 7.

Species	Strike rate (p)
E. microcorys	0.486
E. resinifera	0.429
E. robusta	0.374
E. tereticornis	0.326
M. quinquenervia	0.295
E. eugenioides	0.250
E. propinqua	0.241
E. tindaliae	0.230
S. glomulifera	0.194
E. moluccana	0.181
E. planchoniana	0.179
E. acmenoides	0.177
C. maculata	0.129
E. siderophloia	0.127
E. seeana	0.107
C. intermedia	0.107
A. torulosa	0.104
A. aulocarpa	0.092
E. pilularis	0.087
C. gummifera	0.083
L. suaveolens	0.053

Table 7: Species in primary dataset ranked by strike rate and grouped according to results of G-tests for Independence. Distinct species groups are recognised as primary, secondary and supplementary species.

The Draft Recovery Plan for the Koala (DECC 2003) groups stringybarks and supplementary species together, however Table 7 shows that in the study area local stringybarks (*E. eugenioides, E. tindaliae* and *E. planchoniana*) have significantly higher use than supplementary species.

Use versus Availability (U-A)

U-A measures are shown for *Eucalyptus* species in Figure 3. The graph also indicates the effects of a large spread in U-A levels from site to site, in the case of *E. eugenioides* the high average U-A appears to be skewed by two sites with high U-A. If *E. eugenioides* is excluded on this basis then *E. propinqua* has the second-highest U-A with *E. tereticornis* in third position followed by *E. seeana*. *E. microcorys* has a much higher U-A than any species. In contrast, *E. moluccana, E. pilularis* and *E. siderophloia* have a negative U-A, indicating that these species are not preferred by

Koalas and may even be avoided. *E. planchoniana* has the lowest U-A of any eucalypt indicating that this may not be a secondary species as ranked by the G-test.

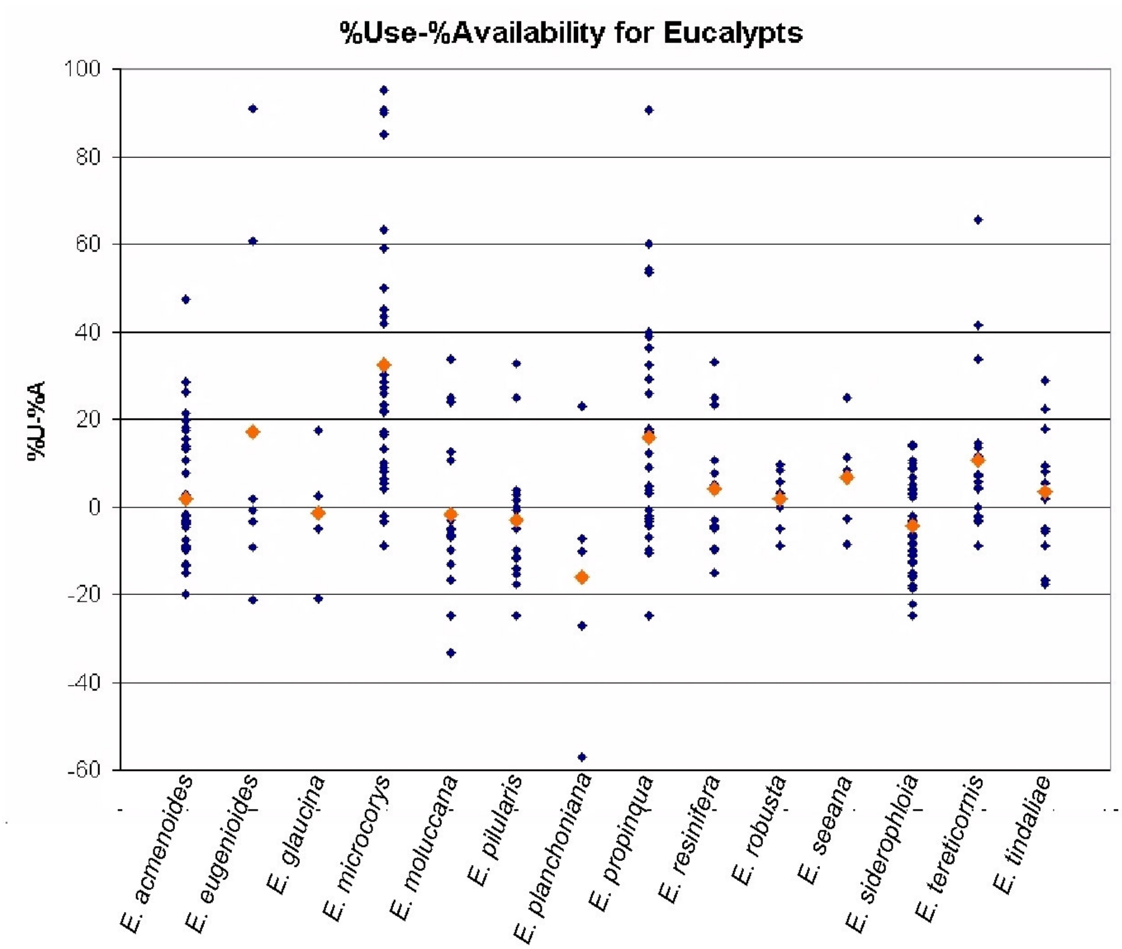

Figure 3: Usage (%) – Availability (%) for *Eucalyptus* species at each SAT site (blue diamond) in the study area. Species with a value > 0 are actively sought by Koalas. Mean %U-%A for each species shown in red.

Figure 4 shows U-A analysis of non-eucalypts, with the exception of *Syncarpia glomulifera* these species are used in less proportion to their availability, an indication that *S. glomulifera* may be an important shelter tree for Koalas.

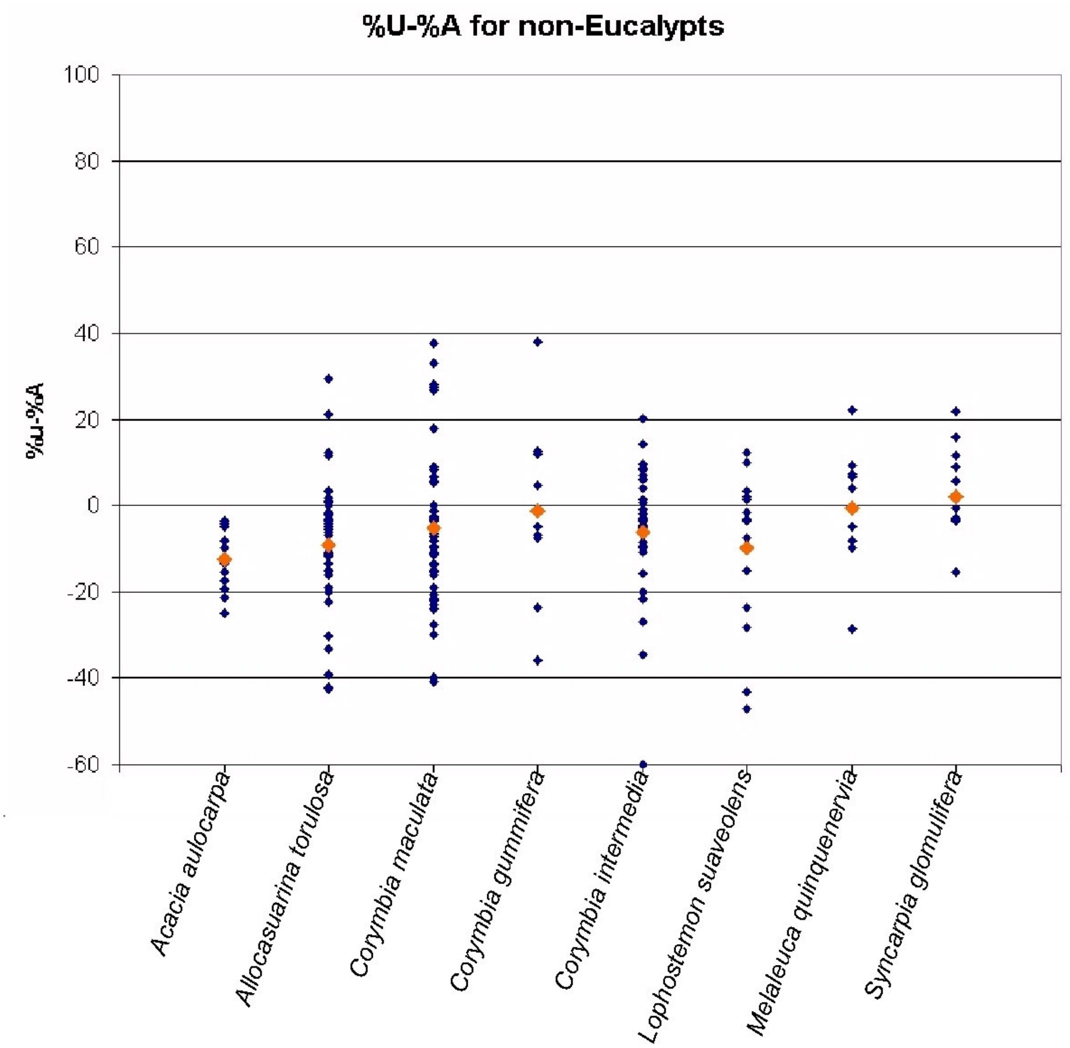

Figure 4: Usage (%) – Availability (%) for non-*Eucalyptus* species in the study area.

Utilisation of Secondary Species

Utilisation of some tree species may change when primary tree species are present. Some species did not appear to grow with primary tree species, for example *E. resinifera, E. eugenioides* and *E. pilularis* were not sampled in association with *E. tereticornis*. For those species combinations with adequate data for comparison (at least 3 sites with a primary species, and at least 3 corresponding sites without primary species) the significance or otherwise of eucalypts growing with the primary species *E. tereticornis* and *E. microcorys* was tested by using the Mann-Whitney U-test to compare site U-A levels for species with and without primary tree species present. Results are shown in Table 8 with significant *p* values in bold.

Species	average U-A with *E. microcorys*	average U-A without *E. microcorys*	*p* value
E. acmeniodes	-2.7	5.6	**0.0167**
E. eugenioides	12.1	20.6	0.2397
E. moluccana	-5.0	-1.2	0.4115
E. pilularis	-4.9	0.4	0.2871
E.propinqua	-0.7	23.6	**0.0023**
E. resinifera	-0.3	14.9	**0.0330**
E. siderophloia	-1.0	-5.6	0.1120
E. tindaliae	2.0	3.6	0.3677
Species	**average U-A with *E. tereticornis***	**average U-A without *E. tereticornis***	***p* value**
E. acmeniodes	15.4	0.6	**0.0289**
E. moluccana	1.0	-2.8	0.3906
E.propinqua	4.6	18.5	0.1840
E. siderophloia	-5.1	-4.1	0.2755

Table 8: Mann-Whitney U-test to determine influence of primary tree species on Usage-Availability (%) of secondary tree species. Bold *p* values indicate significant influence.

It is reasonable to expect that use of secondary tree species would increase in the absence of primary tree species. With the four significant cases in Table 8 this is indeed the case for *E. acmeniodes* (p = 0.0167)*, E.propinqua* (p = 0.0023) *and E. resinifera* (p = 0.0330) when they grow with *E. microcorys.* However utilisation of *E. acmeniodes* decreases markedly (p = 0.0289) in the absence of *E. tereticornis*. It is recommended on this basis that *E. acmeniodes* be ranked as secondary where it grows in vegetation communities with *E. tereticornis*, and classed as a supplementary species where it grows with *E. microcorys*.

Substrate Based Levels of Utilisation

Significant levels of utilisation were largely confined to three broad geological units (Sandstones, Quaternary Deposits and Coal Measures) recognised for the purposes of the study. No active sites were found on volcanic substrates despite extensive searches. Each SAT site was assigned to a geological unit using a combination of 1:250,000 geology maps, Landsat imagery and airborne radiometric data. Table 9 shows the number of sites, number of trees and average activity level on each of the three geology units. Utilisation levels were significantly much higher on Quaternary substrates than other substrates (G_{adj} = 68.1019 (p = 1.665 10^-15) > $X^2_{.05[2]}$).

Geology unit	No. of sites	No. of trees	No. trees with pellets	Av. Activity (%)
Quaternary	19	614	208	33.88
Sandstones	60	2113	398	18.84
Coal Measures	11	382	68	17.80

Table 9: Summary of SAT site data on the three main geology units in the study area.

Quaternary substrates

E. robusta and *M. quinquinervia* were the only species to satisfy the criteria for rigid statistical analysis, with no significant difference in utilisation between the two species (G_{adj} = 0.044 (p = 0.8346) < $X^2_{.05[1]}$). On this basis and the ranking in G-tests *M. quinquinervia* is classed as a Koala shelter species. Indeed, *M. quinquinervia* may even be used as a supplementary food tree, and should be regarded as an integral part of vegetation communities containing *E. robusta*.

E. tereticornis was found on five sites with all 37 trees recording pellets and on this basis is ranked as a primary tree species on Quaternary substrates.

Sandstone substrates

Thirteen species were suitable for analysis using the iterative G-test technique. *E. microcorys* and *E. tereticornis* are the primary tree species on Sandstone substrates. However, *E. microcorys* had significantly higher use than *E. tereticornis* (G_{adj} = 8.7993 (p = 0.0123)> $X^2_{.05[1]}$). *E. propinqua* has significantly higher use than other tree species (G_{adj} = 36.4129 (p = 7.147 10^-5> $X^2_{.05[1]}$) and so can be regarded as the most important secondary tree species (G_{adj} = 87.9140 (p =0) > $X^2_{.05[3]}$). Results for Sandstone substrates are shown in Table 10. The fourth group (*S. glomulifera, E. tindaliae, E. moluccana* and *E. acmenoides*) comprise a group of shelter and supplementary food tree species on sandstone substrates.

Species	Strike rate (p)
E. microcorys	0.542
E. tereticornis	0.439
E. propinqua	0.335
S. glomulifera	0.260
E. tindaliae	0.237
E. moluccana	0.211
E. acmenoides	0.210
C. intermedia	0.184
E. pilularis	0.178
E. siderophloia	0.155
C. maculata	0.139
A. torulosa	0.134
C. gummifera	0.127

Table 10: Species in Sandstones primary dataset ranked by strike rate and grouped according to results of G-tests for Independence.

Coal Measures substrates

Analysis of limited data for species on Coal Measures provided results which should be viewed with caution, with *E. resinifera* and *E. microcorys* the preferred tree species, and *E. siderophloia, E. acmenioides* and *E. propinqua* grouped as secondary species (G_{adj} = 26.341 (p = 2.861 10^-7) > $X^2{}_{.05[3]}$). Species, the number of sites used for G-tests and strike rates are shown in Table 11.

Species	No. sites	Strike rate (p)
M. quinquenervia	1	1.00
E. resinifera	4	0.68
E. microcorys	6	0.62
L. suaveolens	2	0.24
E. siderophloia	5	0.18
E. acmenoides	7	0.16
E. propinqua	6	0.16

Table 11: Species on Coal Measures ranked by strike rate and grouped according to results of G-tests for Independence. Results should be viewed cautiously with regard to the number of sites.

Comparisons of Species on different substrates

Comparisons using G-tests were made for those eucalypts with higher strike rates on different substrates. Using less stringent methods for *E. tereticornis* (with only 5 sites on Quaternary substrates) utilisation of this species appeared to be significantly higher on Quaternary than Sandstone substrates (G_{adj} = 32.863 (p = 9.890 10^-9)< $X^2_{.05[1]}$). *E. microcorys* on Coal Measures (with 6 sites) was not significantly different to Sandstone substrates (G_{adj} = 0.036 (p = 0.8499)< $X^2_{.05[1]}$)

There was significantly higher utilisation of *E. resinifera* on Coal Measures (4 sites) than on Sandstones (G_{adj} = 3.981 (p = 0.0460)< $X^2_{.05[1]}$), whereas use of *E. propinqua* was not significantly different on these substrates (G_{adj} = 3.778 (p = 0.0519)< $X^2_{.05[1]}$).

U-A for secondary species was also examined on Sandstone substrates with and without primary species present and shown in Figure 12. *E. propinqua* was the only species with significantly higher utilisation in the absence of primary species confirming this species' rank as a secondary food tree.

Species	**average U-A with Primary trees**	**average U-A without Primary trees**	***p* value**
E. acmeniodes	-0.335	3.1	0.2058
E. eugenioides	19.7	26.9	0.4136
E. moluccana	0.0	-2.2	0.4203
E. pilularis	-4.9	1.1	0.2991
E.propinqua	2.3	23.6	**0.0003**
E. siderophloia	-3.9	-6.7	0.3097
E. tindaliae	4.0	2.4	0.4432

Table 12: Mann-Whitney U-test to determine influence of primary tree species on Usage-Availability (%) of secondary tree species on Sandstone substrates. *E. propinqua* was the only species demonstrating a significant difference in utilisation.

The Use of Non-eucalypts

Referring to Table 4, eight species of non-eucalypt satisfied the selection criteria for analysis using G-tests of Independence. The extent of variation in levels of utilisation of these eight species was significant across all substrates (G-Test for Goodness of Fit G_{adj} = 42.3473 (p = 4.458 10^-7) < $\square^2_{.05[7]}$). The result of an Unplanned Tests of Homogeneity of Replicates indicated a significantly higher level of utilisation for

Melaleuca quinquenervia and *Syncarpia glomulifera* than other species (G_{adj} = 15.2849 (p = 0.0005)< $\chi^2_{.05[2]}$) but with these two species separated in the reverse direction G_{adj} = 15.2849 (p = 0.0005)< $\chi^2_{.05[2]}$). A higher level of utilisation for these species indicates that they are favoured shelter species for Koalas, a result also indicated by the Usage versus Availability analysis shown previously in Figure 4. The reverse direction also distinguishes *Corymbia maculata* from the remaining species and ranks it with *S. glomulifera* (G_{adj} = 13.3604 (p = 0.0202)< $\chi^2_{.05[2]}$). However *S. glomulifera* is probably more important as a shelter tree owing to its rarity compared with *C. maculata*. Table 13 shows the rankings for non-eucalypts in the primary dataset.

Species (forward)	Strike rate (p)	Species (reverse)	Strike rate (p)
M. quinquenervia	0.29	*M. quinquenervia*	0.29
S. glomulifera	0.19		
		S. glomulifera	0.19
C. maculata	0.13	*C. maculata*	0.13
C. intermedia	0.11		
A. torulosa	0.10	*C. intermedia*	0.11
A. aulocarpa	0.09	*A. torulosa*	0.10
C. gummifera	0.08	*A. aulocarpa*	0.09
		C. gummifera	0.08
L. suaveolens	0.05	*L. suaveolens*	0.05

Table 13: Non-eucalypt species in the primary dataset ranked by strike rate and grouped according to results of G-tests for Independence. Forward and reverse comparisons gave slightly different groupings.

Tree species rankings

Table 14 summarises the food and shelter rankings for tree species in the Richmond Valley area. The preference ranking of tree species by many different statistical tests can be problematic as seemingly conflicting results may be obtained. Interpretation of these results requires some pre-existing knowledge of Koala habitat use while at the same time adding valuable insights to this knowledge. Tree species analysed with data collected during this study are shown with the associated statistical tests. For species ranked as “likely” the precautionary principle has been adopted when data are lacking and reference has been made to AKF data from other North Coast areas (AKF) or from DECC’s Draft Recovery Plan for the Koala (DRP).

Food Species	Rank	Criteria
E. acmenioides	Supplementary except below	G-test/U-A/U-A with/without Prim. species
E. acmenoides	Sec. with *E. tereticornis* or on Coal Measures	G-test/U-A/U-A with/without Prim. species
E. amplifolia	likely Primary	DRP
E. bancroftii	likely Primary	AKF/DRP
E. carnea	likely Secondary	AKF/DRP
E. crebra	Supplementary	DRP
E. eugenioides	Supplementary	G-test/U-A/U-A with/without Prim. species
E. fibrosa	Supplementary	DRP
E. glaucina	likely Secondary	DRP
E. grandis	likely Supplementary	AKF
E. microcorys	Primary all substrates	G-test/U-A/AKF/DRP
E. moluccana	Supplementary	G-test/U-A/U-A with/without Prim. species
E. pilularis	Supplementary	G-test/U-A/AKF/DRP
E. planchoniana	Supplementary	AKF
E. propinqua	Secondary	G-test/U-A/U-A with/without Prim. species
E. resinifera	Prim. on Coal Measures (otherwise Sec.)	G-test/G-test on substrates (U-A,AKF,DRP)
E. robusta	Primary on Quaternary	G-test/U-A/AKF/DRP
E. rummeryi	likely Secondary	DRP
E. saligna	likely Supplementary	AKF/DRP
E. seeana	likely Primary	U-A /DRP
E. siderophloia	Sec. on Coal Measures, otherwise Supp.	G-test/G-test on substrates/U-A
E. signata	likely Secondary	AKF
E. tereticornis	Primary all substrates	G-test/U-A/AKF
E. tindaliae	likely Secondary on Sandstones	G-test on sandstone/U-A/AKF
Shelter Species		
A. aulocarpa	Other	G-test/U-A/G-test for non-eucalypts
A. bakeri	Other	Strike rate/*A. floribunda*/AKF
A. floribunda	Other	Strike rate/AKF
A. litoralis	Other	Strike rate/AKF
A. melanoxylon	Other	Strike rate/AKF
A. subvelutina	Other	Strike rate/*A. floribunda*/AKF
A. torulosa	Other	G-test/U-A/G-test for non-eucalypts
B. integrifolia	Other	Strike rate/AKF
B. serrata	Other	Strike rate/AKF
C. glauca	Other	Strike rate/AKF
C. gummifera	Other	G-test/U-A
C. henryii	Other	AKF (based on *C. maculata*)
C. intermedia	Other	G-test/U-A/G-test for non-eucalypts
C. maculata	Other	G-test/U-A/G-test for non-eucalypts
E. sieberi	Other	Strike rate/AKF
L. confertus	Other	Strike rate/AKF
L. suaveolens	Other	G-test/U-A/G-test for non-eucalypts
M. quinquenervia	Shelter/supplementary food tree	G-test/G-test substrates/U-A/G-test non-eucs
S. glomulifera	Shelter	G-test/U-A/G-test for non-eucalypts

Table 14: Final rankings of tree species as food trees and shelter trees showing ranking criteria. “Likely” ranks are assigned from sources other than this study (AKF unpublished data or Draft Recovery Plan for the Koala).

4.2 Koala Habitat Atlas

Derivation of a Koala Habitat Atlas for the study area is a matter of assigning a Koala Habitat category to each vegetation polygon according to the percentage of Primary, Secondary, Supplementary, Shelter and Other tree species listed in Table 8. This percentage is derived using the Vegetation Community Descriptions in Appendix 3 of Ecograph's "Richmond Valley Remnant Vegetation 2004" report combined with data from active and inactive SAT sites to give an accurate indication of the actual tree species percentages in each Community. Vegetation Communities are listed in Appendix 2 of this report, along with the assigned Koala Habitat category. Using MapInfo software, Habitat categories were added to a copy of the vegetation map as an additional map attribute. Although individual Vegetation Communities typically occur on one substrate, they were assigned a substrate category (Quaternary, Sandstones, Coal Measures) to distinguish communities containing tree species with differing utilisation rates on different substrates. Each Koala Habitat category was then combined to provide a total area of each Habitat category, then disaggregated to provide contiguous polygons for each type (which may be a combination of adjoining vegetation communities). The area of each polygon is then updated.

Vegetation Community 116 – Lowland Riparian Complex is an amalgam of different communities ranging from River Oak (*Allcasuarina cunninghamiana)* communities through to Flooded Gum (*Eucalyptus grandis*) and other floodplain and near-coastal communities. Examination of SAT site data indicates that they are likely to contain primary food trees, respectively *E. tereticornis* (River Oak community)*, E. microcorys* (Flooded Gum), and *E. robusta* and *E. tereticornis* (and/or other Red Gums) in enough quantities for these communities to be ranked as Secondary Habitat Class 'B'.

Wet/Dry Heathland Communities were mapped as broad units, however these communities certainly contain pockets of primary and secondary Koala food trees. The description of Vegetation Community 143 – Dry Heathland does not state *E. robusta* to be a member of this community although eight SAT sites in this community sampled *E. robusta* including seven with evidence of use by Koalas. Although E. *robusta* is probably only found in swale areas of these communities, it seems prudent to upgrade this community to Secondary Habitat Class 'C' to capture this primary Koala food tree.

For vegetation communities with tree species not sampled by SAT sites the Koala food trees ranked in Appendix Two of the Draft Recovery Plan for the Koala (DECC 2003) have been applied to categorise vegetation units in conjunction with AKF data from other north coast areas. The final Koala Habitat Atlas is shown in Figure 5, with areas of each Habitat Class shown in Table 15.

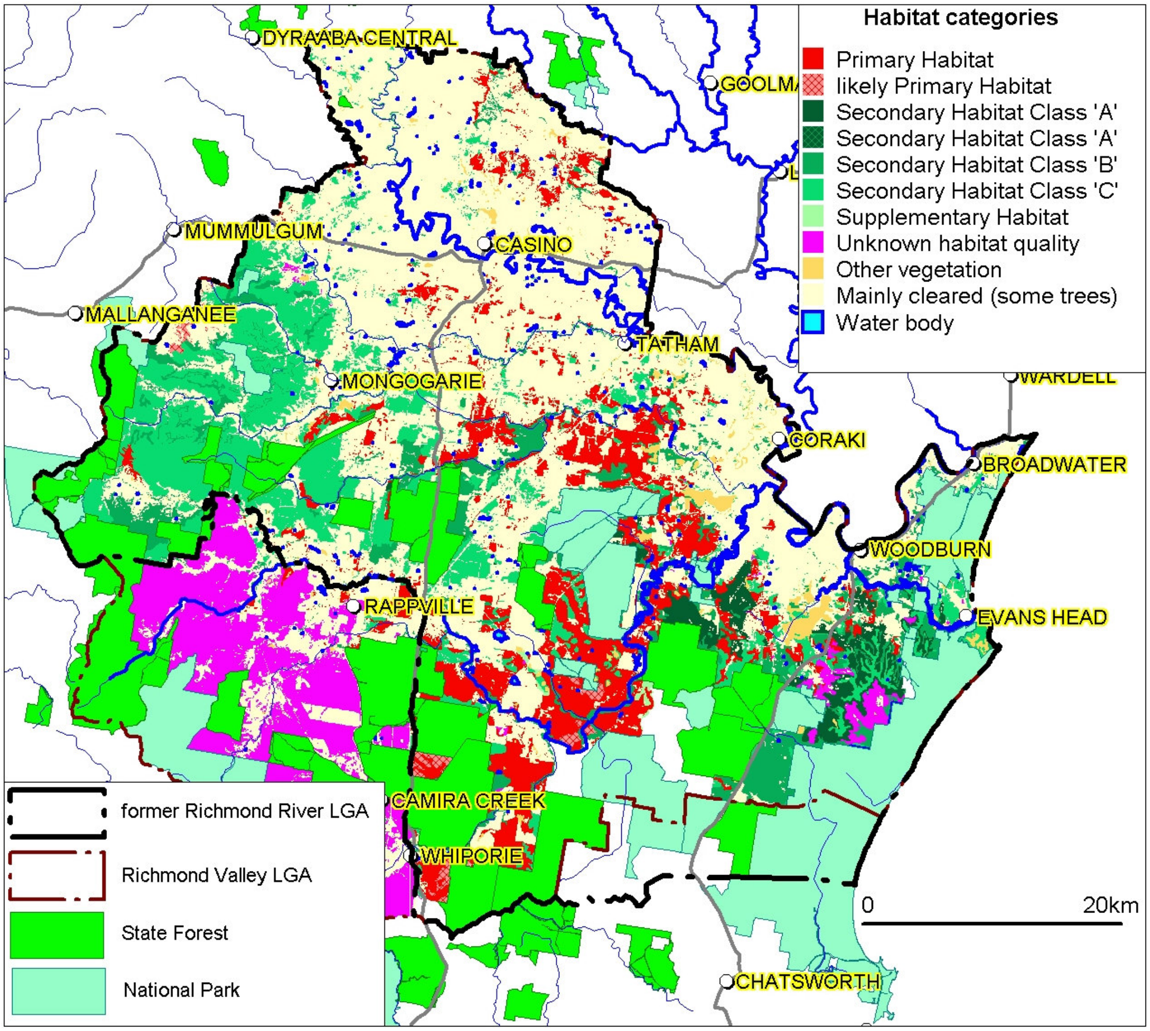

Figure 5: Koala Habitat Atlas for the study area. The former Richmond River LGA (study area) is shown with a black line. Unmapped areas include State Forests and National Parks.

Habitat category	Area (ha)	percent of mapped area
Primary Habitat	23749	11.9
likely Primary Habitat	1107	0.6
Secondary Habitat Class 'A'	4613	2.3
likely Secondary Habitat Class 'A'	2	0.0
Secondary Habitat Class 'B'	18237	9.2
Secondary Habitat Class 'C'	29344	14.7
Supplementary Habitat	324	0.2
Other vegetation	3566	1.8
Mainly cleared (some trees)	116684	58.6
Water body	1509	0.8
Total mapped area	199135	100.0
Unknown habitat quality/unmapped	46246	

Table 15: Areas of each Koala Habitat Class. Unmapped areas and Water bodies excluded from areas.

The mapped area is composed of Primary Koala Habitat (24,856 ha 12.5% including "likely" Primary Habitat) which occupies extensive areas of Red Gum communities along alluvial plains adjoining Bungawalbin, Myrtle, Myall and Sandy Creeks. Smaller areas of Primary Habitat (Forest Red Gum) are scattered across the Richmond River alluvial plain and on uncleared upper slopes north of the River. Primary Habitat also includes five mapped areas of Swamp Mahogany, however there are many small unmapped pockets of this species in swales on Pleistocene soils adjoining Broadwater and Bundjalung National Parks. These pockets lie within vegetation mapped as Heathland communities. All these areas of Primary Habitat are found on Quaternary substrates.

Secondary Habitat Class 'A' (4,615 ha 2.3% including "likely" Secondary Habitat Class 'A') is predominantly located east of the Pacific Highway between Esk and Evans Rivers where communities with 30-50%Tallowwood occur on midslopes of the coastal range. An additional area of Tallowwood forest with extensive Koala evidence occurred on a long ridge north of Doubleduke State Forest. Grey Gum and Red Mahogany communities occupy upper slopes south of Evans River, with additional areas of Grey Gum-dominated forests on midslopes adjoining Doubleduke SF.

Secondary Habitat Class 'B' (18,237 ha 9.2%) occurs in three major areas within the study area. Grey Box communities containing Forest Red Gum occupy mid- and lower-slope positions adjoining Braemar and Ellangowan State Forests and extending along Sandy Creek. Low-density but significant Koala activity was recorded in these Forests. Koala activity was recorded in the far west of the LGA in Blackbutt and

Flooded Gum communities containing Tallowwood as a sub-dominant species, particularly southeast of Mummulgum and in Cherry Tree and Mount Belmore SFs. Needlebark Stringybark communities on Coal Measures near Tabbimobile containing some Red Mahogany and occasional Tallowwood are also included in this Habitat Class.

Secondary Habitat Class ‘C’ (29,344 ha 14.7%) occurs extensively across the southern half of the study area and is composed of Spotted Gum communities containing some Grey Gum and Forest Red Gum. Estuarine Swamp Oak communities which may contain traces of Swamp Mahogany or Forest Red Gum are also included as are Paperbark and Heathland Communities adjoining Broadwater and Bundjalung National Parks with patches of Swamp Mahogany and/or Red Gum which were not mapped in detail, however within these communities Koala faecal pellets were recorded from seven SAT sites with Swamp Mahogany.

Supplementary Koala Habitat (324 ha 0.2%) is composed of drier Blackbutt, Bloodwood and Apple communities with no Koala food trees present. Patches are generally small and isolated from other areas of forest.

Added together these habitat categories constitute 77,376 ha or 38.9% of the mapped area. An additional 194 ha was not typed during the mapping exercise or was composed of unidentified acacia-schlerophyll regenerating vegetation.

5.0 DISCUSSION

The results of this study support a model of habitat utilisation by Koalas that is principally focused on three species of eucalypt: Forest Red Gum *Eucalyptus tereticornis,* Swamp Mahogany *E. robusta* and Tallowwood *E. microcorys*, each of which can be shown to be the subject of preferential utilisation by Koalas in the study area. The first two species are primarily found on Quaternary substrates which have almost twice the level of Koala utilisation of other substrates.

In addition, three other species of eucalypt: Grey Gum *E. propinqua*, Grey Ironbark *E. siderophloia* (on Coal Measures substrates) and Red Mahogany *E. resinifera*, also function as significant secondary species, with the latter species ranking equally with

Tallowwood on Coal Measures substrates. Notwithstanding issues associated with various landuse activities and the depredations of both motor vehicles and dogs, the presence of these primary and secondary tree species must be considered to be the major limiting factors affecting the distribution and abundance of remaining Koala populations in the study area.

Both Primary and Secondary Koala Habitat categories can constitute critical habitat from the Koalas' perspective ('Core Habitat' for the purposes of SEPP No. 44). However, each differ significantly in terms of their relevance to long term management of Koalas.

PRIMARY HABITAT - 24,856 ha 12.5% including "likely" Primary Habitat

Areas of forest or woodland where primary Koala food tree species comprise at least 50% of the overstorey trees.

Capable of supporting high-density Koala populations.

SECONDARY HABITAT (CLASS A) - 4,615 ha 2.3% including "likely" 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 overstorey trees; or

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

Areas of forest or woodland where secondary food tree species alone comprise at least 50% of the overstorey trees (primary Koala food tree species absent).
Capable of supporting high to medium-density Koala populations.

SECONDARY HABITAT (CLASS B) - 18,237 ha 9.2%

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

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

Capable of supporting medium to low-density Koala populations.

SECONDARY HABITAT (CLASS C) - 29,344 ha 14.7%

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 overstorey trees.

Capable of supporting low-density Koala populations.

SUPPLEMENTARY/MARGINAL HABITAT - 324 ha 0.2%)

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.

OTHER VEGETATION

Areas of forest or woodland where *Eucalyptus* species are absent, but which have important 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.

The Significance of Activity Indicators

The low levels of utilisation of the preferred tree species by Koalas within the study area in the company of low activity levels generally is considered an artefact of historical habitat clearing and disturbance and a reflection of the localised and often fragmented occurrence of vegetation remnants containing the preferred species. Many of these remnants appear to be unoccupied by extant Koala populations. The low activity levels generally associated with the presence of the preferentially utilised tree species are inconsistent with the results expected on the basis of other Koala Habitat Atlas projects completed to date. With few exceptions, the results obtained during this study are indicative of those likely to be obtained in areas which are largely supporting socially dissolute populations comprised of transients and nomads rather than sedentary breeding aggregations.

Notwithstanding such considerations, in those areas of Primary Koala Habitat currently supporting breeding aggregations, significant levels of activity by Koalas may extend into adjoining areas of Secondary and/or Supplementary Habitat. Such instances are likely to be less of a reflection on the nutritional value of the Supplementary Habitat than their proximity to the significant tree species but in this regard they must be considered an important habitat component from the Koala's perspective, providing secure roosting and interaction areas, and opportunistic browsing opportunities.

Historical research conducted in conjunction with this study indicates that the distribution and abundance of Koalas was historically much greater within the LGA, including from within areas since subjected to extensive vegetation clearing, disturbance and fragmentation.

The modelling of Primary Koala Habitat within the former Richmond River Shire Council planning area involved vegetation associations wherein Forest Red Gum *Eucalyptus tereticornis,* Tallowwood *E. microcorys* and Swamp Mahogany *E. robusta* (primary tree species) are dominant components of the overstorey. Secondary Koala Habitat within the study area includes vegetation associations where either the above species are sub-dominant components of the overstorey or where Grey Gum *E. propinqua*, Grey Ironbark *E. siderophloia* and Red Mahogany *E. resinifera* (secondary tree species) collectively or individually dominate the vegetation community. Supplementary Koala Habitat includes remaining areas of vegetation, other than any areas of 'Unknown' Koala habitat value, where the aforementioned tree species occur at low densities, generally less than 10 %.

Densities of the preferred and secondary tree species were determined on the basis of data from the Koala habitat assessments (SAT sites) together with descriptions for each of the identified floristic associations accompanying the vegetation mapping.

Distribution and Status of the Richmond River Koala Population

Those habitat categories with the greatest potential for effective long term conservation and management of the Koala population include Primary and Secondary Koala habitat which collectively comprise 77,052 hectares or approximately 38.7% of the mapped forested areas within the study area. Field research indicated that a substantial amount of the available habitat either contained Koala populations at very low densities or was not being utilised by Koalas. This contention is supported by the generally low activity levels recorded during fieldwork and the relatively high proportion of inactive sites, including those where only one tree was recorded with a Koala faecal pellet despite the presence of preferentially-utilised tree species.

The extent to which the low Koala population density has been influenced by historical land use practices or threatening processes remains to be quantified. However, historical research undertaken to date has provided sufficient evidence to confirm a significant range contraction by the Koala population of the study area over the last 100 years.

While the actual size and status of the current Koala population for the Richmond River study area must remain speculative, estimations on the basis of the total available Primary and Secondary Koala Habitat identified by the Koala Habitat Atlas in conjunction with the results of fieldwork and extensive foot-based traverses of the study area suggest a relatively small population overall, largely comprised of highly fragmented and dissolute populations with a small number of localised breeding aggregations. It is suggested that at the time of the study (1995-1996) the maximum population size inhabiting the study area was likely to be less than 1,000 individuals, and certainly less than this figure in 2008.

In order to view the population estimate in an appropriate context some consideration must be given to the concept of the “effective” population size, based on an understanding of social structures, breeding systems, reproductive rates and other considerations as they apply to a particular species. Such considerations from the Koala’s perspective suggest an “effective” population size in the study area of between 300 and 500 individuals (figures based on a 50:50 sex ratio at birth and a polygynous social structure with a strong female bias and 35% infertility).

Given a low probability of adequate levels of recruitment from outside of the study area, together with hazards associated with bushfire, further habitat disturbance or removal and predation by domestic and/or feral animals, the remaining Koala population in the Richmond River Local Government Area should be considered as extremely vulnerable over the medium to long term, with several localised populations under threat of extinction.

Consistency with State Environmental Planning Policy No. 44

State Environmental Planning Policy No. 44 - Koala Habitat Protection (SEPP 44) commenced operation in New South Wales on February 13, 1995 with the objective “to encourage the proper conservation and management of areas of natural vegetation that provide habitat for Koalas, to ensure permanent free-living populations over their present range and to reverse the current trend of population decline.”

Aside from requiring the preparation of Koala Management Plans in relation to specific development applications where “core” Koala habitat is involved, SEPP 44 further encourages Councils to prepare comprehensive shire-wide Koala Plans of Management in accordance with set guidelines. The Draft Recovery Plan for the Koala has reviewed these guidelines and a schedule of Koala Feed Tree Species published. This species list is in close agreement with the results of the present study in the case of primary food trees, however with regard to secondary food trees the list should be augmented with additional tree species.

Notwithstanding low densities of Koala found through the study area, all areas of Primary and Secondary Koala Habitat as defined by the Koala Habitat Atlas could potentially constitute “Core” Koala habitat in accordance with SEPP No. 44.

5.0 RECOMMENDATIONS

The following recommendations are considered to be the minimum necessary to provide for the long term viability of Koala populations within the Richmond River Shire Council planning area:

1. Amend Local Environmental Planning documents to reflect the location and significance of identified Primary and Secondary Koala Habitat areas.

2. Initiate and seek government support for a moratorium on any land use activities likely to threaten or otherwise negatively impact upon remaining areas of Primary and Secondary Habitat known to be occupied and/or regularly used by one or more Koalas as evidenced by records of breeding females and/or the presence of Koala faecal pellets.

3. Ensure that any further land clearing activities, development proposals or other land use activities likely to contribute to further fragmentation and/or degradation of remaining areas of Primary or Secondary Koala Habitat and/or individual Forest Red Gum *Eucalyptus tereticornis*, Tallowwood *E. microcorys*, Swamp Mahogany *E. robusta*, Grey Gum *E. propinqua*, Grey Ironbark *E. siderophloia* or Red Mahogany *E. resinifera* trees in areas not known to be occupied and/or regularly utilised by one or more Koalas, are conducted in accordance with Recommendation 12.

4. Institute a Tree Preservation Order over the following Eucalypt species within the Richmond River Shire Council Local Government Area:

Forest Red Gum	*Eucalyptus tereticornis*
Tallowwood	*Eucalyptus microcorys*
Swamp Mahogany	*Eucalyptus robusta*
Grey Gum	*Eucalyptus propinqua*
Red Mahogany	*Eucalyptus resinifera*

5. Modify existing Bushfire Management Plans and/or strategies to reflect the presence of known Koala habitat and especially breeding aggregations and to effectively minimise the risk posed by bushfire to those populations. Strategies appropriate for consideration include:

a) in consultation with the National Parks and Wildlife Service and the Australian Koala Foundation, the construction of radiation/hazard reduction zones around areas of Primary Koala Habitat;

b) the nomination of areas supporting known Koala breeding aggregations as primary response areas in the event of wildfires; and

c) undertake a review of current bushfire management practices in order to minimise bushfire events and to ensure that hazard reduction programs effectively reduce by means of a low intensity “cool burn” no more than 20% of any given area of Primary or Secondary Koala Habitat on a minimum 5 year cycle.

6. Develop Koala management strategies for specific areas where Koala management is an issue. These strategies must address the need for a moratorium on habitat clearance and/or degradation in those areas together with programs for strict domestic dog management, vehicle calming, habitat management and restoration, and community awareness.

7. Design and implement, in conjunction with land holders and the National Parks and Wildlife Service, an effective control program for feral dogs and foxes within the identified Primary and Secondary Koala Habitat areas and adjacent lands.

8. Actively encourage community-based reporting of Koala sightings including females with joeys from within the study area with a view to identifying and monitoring possible locations of remaining breeding aggregations. Consistent with the requirements of SEPP No. 44, maintain a central register for community-based records of past and current Koala distribution within the LGA.

9. Design and implement a long term program to restore and manage Koala habitat including the future possibility (given the more pressing need to secure remaining populations) of creating or enhancing 'habitat links' in suitable areas, in conjunction with local landholders, with a view to restoring ecological integrity and increasing the carrying capacity for Koalas generally.

10. Seek to establish Conservation Agreements for areas of Primary and Secondary Koala Habitat on lands not within a National Park or Nature Reserve.

12. Adopt and enforce through appropriate Development Control Plans or other environmental planning instruments the following policies with respect to proposed developments in areas of Primary, Secondary and Supplementary Koala Habitat as designated by the Koala Habitat Atlas:

Primary Habitat : No further development should be approved within remaining areas of Primary Koala Habitat where there is likely to be any negative impact upon that habitat, measurable in terms of proposals which would result in any gross loss or damage to individual Forest Red Gum *Eucalyptus tereticornis*, Tallowwood *E. microcorys* or Swamp Mahogany *E. robusta*.

i) New Urban Developments - as a condition of Development Consent:

Secondary Habitat:

a) Identify individual trees or clusters of trees known to be important to Koalas in the area, including a survey showing the locations and taxonomic identity of all trees of the following species: Forest Red Gum *Eucalyptus tereticornis*, Tallowwood *E. microcorys*, Swamp Mahogany *E. robusta*, Grey Gum *E. propinqua*, Grey Ironbark *E.*

siderophloia, and/or Red Mahogany *E. resinifera*;

b) Ensure that subdivision design has provided for the effective retention of all trees identified by the above;

c) Impose a minimum lot size of 1,500 square metres to maximise retention of native trees, with building envelopes to take advantage of already cleared areas;

d) ensure that subdivision designs are accompanied by corresponding Landscape Plans that ensure a minimum planting of at least one 'preferred' tree species for every residential allotment created;

e) ensure that trees identified for retention or planting are protected by site-specific Tree Preservation Orders (in the case of tree species additional to those already nominated) and by Covenant in accordance with the Conveyancing Act, together with a legal surety (bond) provided by the developer to ensure that the Covenant can be legally enforced (where necessary) for a minimum period of five years following the issuing of any Development Consent;

f) Enforce strict controls over domestic dog ownership, particularly with respect to roaming domestic dogs but preferably through prohibiting the keeping of domestic dogs altogether;

g) Provide road design standards within subdivisions, by means of traffic calming devices and other methods approved by Richmond River Shire Council, in order to restrict vehicle speeds to a maximum of 40 km/hr at all times; and

h) Ensure that environmental consultants appointed to undertake Koala assessments are accredited and/or recognised Koala authorities and are independently appointed by Council with costs born by the developer.

ii) Environmental Protection Lots (2 hectares minimum) - Within Lands Zoned for that Purpose (as a condition of Development Consent)"

a) As for New Urban Developments-Urban Development Program above, but with the exception of point c) and d).

iii) Existing Urban Developments

a) Identify, delineate and protect areas of significant Koala Habitat including individual trees or clusters of the 'preferred' tree species or trees otherwise known to be of local importance to Koalas;

b) Promote and co-ordinate an urban bushland restoration and management program;

c) Enforce strict controls over domestic dog ownership, particularly with respect to roaming domestic dogs; and

d) Introduce traffic calming devices designed to restrict vehicle speeds to a maximum of 40 km/hr at all times in areas with a known incidence of Koala mortality or injury.

Unknown Habitat

Any development activity or development application involving identified areas of "Unknown" Koala Habitat should be mindful that these areas may otherwise constitute significant Koala habitat. Consequently, they may contribute to habitat available for future recolonisation or re-introduction of Koalas and should not be dismissed as being insignificant Koala habitat unless such a contention is supported by appropriate research.

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Appendix I: Koala Home Range Sizes in NSW North Coast

In a study by AKF on the NSW North Coast, 10 Koalas (4 males and 6 females) were radiotracked with home ranges calculated using harmonic means (AKF unpub. data). For females, home ranges varied between 1.8 and 16.3 ha for females, and 10.8 and 42.8 ha for males, with the highest figure belonging to the group's alpha male who occupied a home range with a high percentage of open farmland, and the lowest belonging to a female in very high-quality habitat (AKF unpub. data). Figure 1 shows the arrangement of Koala home ranges ascertained in this study. Dividing the total area occupied by Koalas by the sum of the home ranges occupied by individual Koalas gives a rough approximation of 20% overlap between home ranges. The Koala home ranges shown in Figure 1 include at least some habitat on either alluvial soils or coastal-sand-flat soils with a high water table and higher nutrient availability.

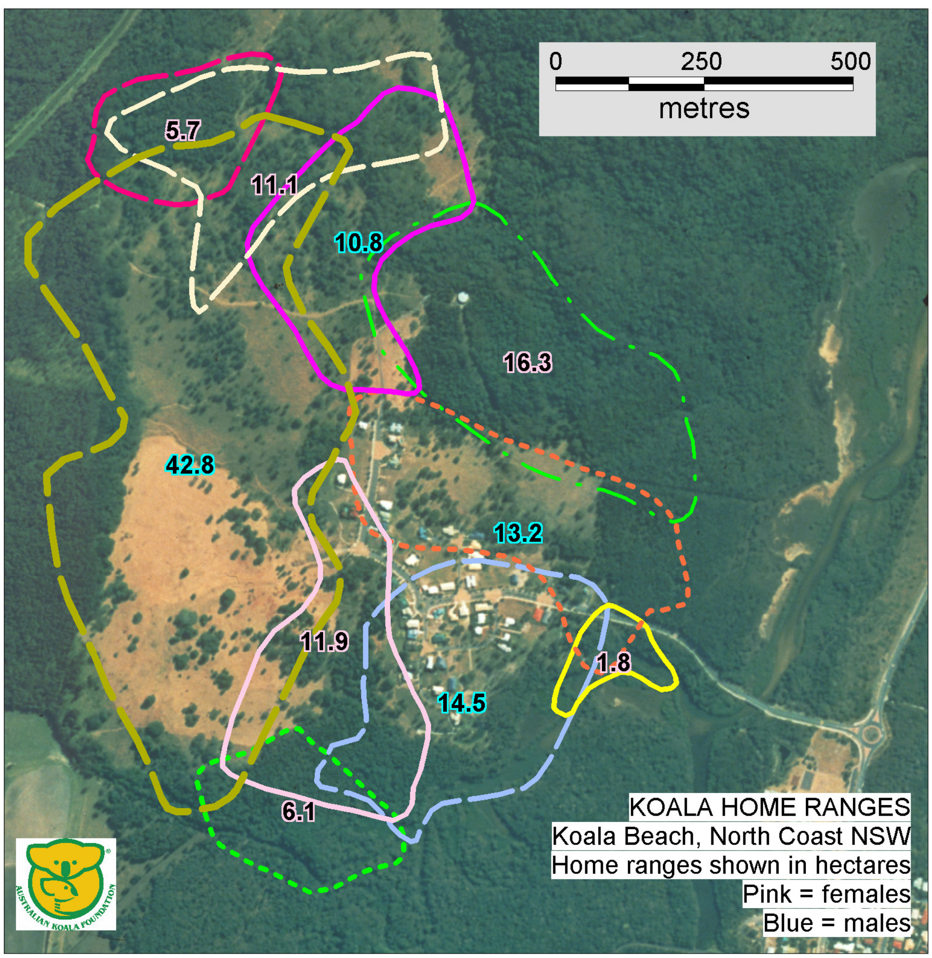

Figure 1: Koala home ranges on the North Coast of NSW (AKF unpub. data).

Appendix II: Vegetation Community Koala Habitat Classes

Vegetation Community	Koala Habitat Atlas category
100 - Eastern Red Gum	likely Primary
101 - Forest Red Gum Complex	Primary
102 - Blackbutt	Supplementary
103 - Pink Bloodwood/Red Bloodwood	Supplementary
104 - Grey Box	2B
105 - Grey Gum	2A
106 - Scribbly Gum	2B
108 - Swamp Mahogany	Primary
109 - Swamp Box	2B
110 - Broad-leaved Apple	Supplementary
112 - Coastal Scleropyll Open Forest Complex	2B
115 - Rough-barked Apple	2C
116 - Lowland Riparian Complex	2B
118 - Coastal Cypress Pine	Other
120 - Ironbark	2B
121 - Broad-leaved Paperbark	2B
122 - Other Melaleuca	2C
123 - Swamp Oak	2C
131 - Floodplain Rainforest	Other
132 - Littoral Rainforest	Other
142 - Banksia Shrubland	2B
143 - Dry Heathland	2C
144 - Wet Heathland	2C
161 - Sedgeland/Wetland	Other
171 - Mangrove/Saltmarsh Complex	Other
181 - Foredune Complex	Other
201 - Forest Red Gum Complex	Primary
202 - Eastern Red Gum	likely Primary
203 - Blackbutt	2B
205 - Spotted Gum Complex	2C
206 - Grey Box	2B
207 - Grey Gum	2A
208 - Pink Bloodwood/Red Bloodwood	2C
209 - Scribbly Gum	2C
210 - Flooded Gum	2B
211 - Tallowwood	2A
212 - Brushbox	2B
213 - Red Mahogany	2A
214 - Needlebark Stringybark	2B
215 - Broad-leaved Apple	2C
216 - Rough-barked Apple	Other
217 - Cypress Pine	Other
218 - Stringybark/Bloodwood	2C
220 - White Mahogany/Red Mahogany/Grey Ironbark/Grey Gum	2B
221 - Ironbark	2B
222 - Grey Box/Forest Red Gum	2A
223 - Steel Box	likely 2A
231 - Dry Rainforest	Other
232 - Sub-tropical Rainforest	Other
242 - Headland Complex	Other
303 - Camphor Laurel	Other
308 - Cultural Planting	Other
333 - Untyped	Unknown
351 - Acacia/Sclerophyll Regeneration	Unknown
401 - Open Water	Water body
501 - Cleared	Mainly cleared (some trees)