Koala Habitat Atlas

Project No. 5 : Campbelltown Local Government Area

Prepared for Campbelltown City Council

by

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EXECUTIVE SUMMARY

An assessment of tree preferences and habitat utilisation by koalas was conducted in the Campbelltown Local Government Area between April of 1994 and March of 1996. A total of 2499 trees comprised of 1159 eucalypts and 1340 non-eucalypts from 45 independent field sites were assessed during the study.

Tree species preferences from a koala's perspective were determined on the basis of a comparative analysis of the proportional strike rates for eleven of the thirty two tree species sampled according to their respective occurrence on each of the two main land units recognised for the purposes of the study. The results have established that two species of eucalypt namely, Grey Gum *Eucalyptus punctata* and Blue-leaved Stringybark *Eucalyptus agglomerata* are the subject of significant levels of utilisation by koalas. This is particularly the case for *E. punctata* when occurring in association with either shale benching or outcropping shale deposits including those on the plateau tops. The significance of both
E. punctata and *E. agglomerata* on substrates derived from shales, as compared to that recorded for the same species on sandstones, indicates that the importance from a koala's perspective of these species is strongly influenced by factors such as micro-changes in the level of soil nutrients. The occurrence of these two eucalypt species, combined with the localised distribution of shale-derived soils appear to be the major limiting factors affecting the distribution, abundance and autecology of koalas inhabiting the study area.

The Koala Habitat Atlas for the Campbelltown Local Government Area identified a total of 2,264.7 hectares of Secondary Koala Habitat-Class A (7.3 % of the overall council area and 14.2 % of the remaining vegetated area); 2,360.7 hectares of Secondary Koala Habitat-Class B (7.6 % of the overall council area and 14.8 % of the remaining vegetated area); 11,222.1 hectares of Marginal Koala Habitat (36.0 % of the overall council area and 70.3 % of the remaining vegetated area). Added together, these categories of koala habitat constitute a total area of 15,847.5 hectares or approximately 50.8 % of the 31,166.5 hectare council area. A further 109.4 hectares of 'Unknown' Koala Habitat (0.3 % of the overall

council area and 0.7 % of the remaining vegetated area) were also identified. In accordance with Koala Habitat Atlas definitions, no areas of Primary Koala Habitat could be ascertained within the area currently being utilised by the koala population.

Further historical research may provide evidence to confirm a significant range contraction by the area's koala population over the last approximately 100 years in conjunction with habitat clearing to the extent that the remaining populations are now largely confined to areas of secondary and/or marginal habitat.

Based on a considered but speculative estimate of the total population for the study area of approximately 100 individuals the "effective" population size is already potentially below the minimum required to afford a guaranteed level of medium term longevity. This is particularly likely to be the case given the potential consequences associated with factors such as severe bushfire, clearing of areas of significant habitat or any inappropriate planning measures otherwise intended to minimise impacts on koalas generally. Consequently, in the absence of a proactive and assertive management strategy, the medium to long term prognosis for the population suggests that localised extinction is possible within thirty to fifty years, or less in the event of widespread high intensity bushfire.

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 more recently the *Threatened Species Conservation Act 1995,* the report concludes that, realistically, the long term conservation and management of the population 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 urgently recommended to give some effect to the implications that arise from this study. Such recommendations include

inter alia, an immediate moratorium on further destruction or modification of significant habitat areas, the recognition and establishment of urban koala management zones with appropriate controls on motor vehicle speeds and the keeping of domestic dogs and legal sureties to enforce proposed 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.

1.0 INTRODUCTION

This report relates to a study of koalas and their habitat in the Campbelltown Local Government Area (LGA) south west of Sydney. The study area falls within the latitudes 33^0 58' and 34^0 10' south and longitudes 150^0 44' and 150 ^{0} 56' east and is bounded to the southwest by the Nepean River and by the Georges River to the northeast. The Campbelltown LGA incorporates the Holsworthy Military Reserve in the east and the northern section of the Wedderburn Plateau in the south.

The Campbelltown LGA is significant in terms of the remaining Koalas of the Sydney region. The Australian Koala Foundation has undertaken this study for the Campbelltown City Council in accordance with the specific objectives outlined below.

1.1 Study Objectives

The aims of the koala Habitat Atlas are to:

a) quantify tree preference and habitat utilisation;
b) delineate significant areas of koala Habitat;
c) examine this information in relationship to SEPP No. 44;
d) identify threatening processes; and
e) recommend measures to provide koala populations with reasonable long term viability.

1.2 Habitat Utilisation by Koalas

The Koala *Phascolarctos cinereus* is an obligate folivore, which feeds primarily, but not exclusively, on the genus *Eucalyptus*. Throughout their range in eastern and south-eastern Australia, koalas have been recorded as utilising a wide variety of eucalypt and non-eucalypt species (Murray, 1988; Hindell & Lee, 1991; Phillips, 1990). While these accounts tend to portray koalas as opportunistic feeders, within a particular area, only a few species of eucalypt will be regularly 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). Edaphic characteristics are also considered to further influence the suitability of several important browse species (Cork & Braithwaite, 1996).

In a socially stable population, koalas coexist in a matrix of overlapping home range areas. Within each animals home range area are a disproportionately small number of trees that are visited repeatedly (Eberhard, 1972; Faulks, 1990; Mitchell, 1990; Phillips, unpub data). Fidelity to the home range area by the constituent koalas is long term and can extend over many years (Lee & Martin, 1988; Mitchell, 1990; Mitchell and Martin, 1990). Increasing evidence provided from the records of koala welfare groups suggests that, in the absence of undue disturbance, such fidelity within the framework of a stable breeding aggregation may extend for the term of the resident animal's lifespan.

The home range areas required by koalas vary in response to social factors and habitat quality. The sex of the animal is also important. Female koalas tend to occupy smaller home range areas than males. While this may be a function of the significantly larger body size of male koalas generally, it is also typical of a polygynous social structure wherein the home ranges of breeding males often overlap those of several adult females.

The relatively sedentary and localised movements of koalas in a socially stable breeding aggregation are a stark contrast to the movements of dispersing sub adults (of both sexes) and other transient members of koala society. These animals, often surplus males, tend to

maintain ephemeral home ranges and are capable of extensive movements (in excess of 40-50km) (Phillips, unpub data). Breeding activity usually initiates the dispersal phase for sub-adults. Clearly, the movements and survivorship of dispersing sub-adults and other nomadic members of koala society are significant within the context of maintaining recruitment levels and genetic vigour in otherwise clustered and spatially segregated breeding aggregations.

Apart from the more widely known problems associated with the presence of Chlamydial organisms in free ranging koala populations, the problems facing wild koalas have not been documented to the same extent as those resulting from studies of disturbed or intensively managed populations. While pathogens such as *Chlamydia spp* are an important component of the koala's natural history and clearly play a role in the natural regulation of undisturbed populations, increasingly fire and other landuse activities such as logging can be shown to be having a significant impact on koala populations, particularly where important food tree species are being effected. Wildfire can potentially result in mortality as high as 60-70% of an area's breeding population, with recovery dependant upon factors such as the size and composition of the remaining population, recruitment levels from adjoining populations and the subsequent frequency and intensity of further fire. Additionally, activities such as logging, sand mining, clearing for agriculture and urban development can contribute to social instability through the removal of home range trees in the first instance, and nutritional stress through the removal of important browse species in the second. Both of these factors contribute to social dissolution, a reduced reproductive potential, increased susceptibility to disease and population decline. In an urban environment, koalas are known to face elevated threats associated with domestic dog attack and road mortality. In addition, predation by feral animals, particularly dogs and foxes, is increasingly being recognised as a significant issue affecting the conservation and management of koala populations occupying rural, semi-rural and bushland areas.

The management of free ranging koala populations is problematical. Despite legislation promulgated to provide protection for koalas and other Australian wildlife, koala populations in New South Wales at least, are continuing to decline (Reed & Lunney, 1990).

Nor is there any evidence, with the possible exception of some island populations in Victoria and South Australia, to support a contention that the decline is not more widespread. Effective conservation and management of koalas, in association with urban, agricultural and silvicultural activities, requires more than simply protecting what are believed to be the "right" trees, ensuring the retention of a few arbitrarily selected food trees, or plantings to compensate for the removal of more mature trees. Inevitably, the lack of any realistic assessment and consideration of the needs of koala populations leads to a gradual decline in koala numbers to the point where localised extinctions are often the end result (Smith & Smith, 1990). The ability of koala populations to apparently sustain themselves following a deleterious impact is more a reflection of the species relative longevity than it is any other factor, a contention most recently noted by Lunney and 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.

1.3 Description of the Study Area

Location

The City of Campbelltown is located approximately 40 kilometres southwest of Sydney, New South Wales (see Figure 1). The Campbelltown Local Government Area (the study area) covers a total area of 311.61 square kilometres (31,161 hectares), approximately 151.74 square kilometres (15,174 hectares) or 48.7 % of which has been predominantly cleared. The South Western Freeway passes through the north western section of the study area. The north western and western sections of the Campbelltown Local Government Area have undergone intensive land clearing for rural and urban development.

Climatic Conditions

The climate of the study area can best be described as temperate with warm to hot summers (maximum temperatures in excess of 30 degrees) and cool to mild winters. The area experiences wettest periods in the months of January-February and June with annual rainfall generally in the range of 700 to 900 mm.

Topography and Geomorphology

The Campbelltown Local Government Area predominately includes sandstone and plateau landscapes with the eastern and southern parts deeply dissected by steep sided gorges associated with O'Hares, Williams and Pheasants Creeks, and the Nepean, Woronora and Georges Rivers. Elevations within the study area range from approximately 150 metres Above Sea Level (ASL) in the gorges to 240 metres Above Sea Level (ASL) on the plateau.

The east and south of the study area is characterised by Hawkesbury Sandstone geology and geomorphology, with steep near vertical cliffed benches along the Georges River and wide stepped platforms exposing prominent interbedded shale layers associated with O'Hares and Pheasants Creeks. On the plateau tops transitional beds of shale and sandstone are a common occurrence and are often exposed on plateau areas to produce an impervious layer with associated 'hanging swamps'. In western and northern sections of the study area the landscape is dominated by gentle undulating rises associated with Wianamatta Shale formations. Floodplain landscapes, including the southern section of the Cumberland Plain, occur in the far north and west of the study area.

Soil types within the study area range from predominantly yellow earths, sandy skeletal podzols and red podzols associated with plateau formations to brown, red and yellow podzols and prairie soils on the Wianamatta Shales. The yellow earth soils are generally confined to residual plateau tops where the underlying strata is composed of a lightly cemented quartz rich sandstone. The podzolic soils have produced a clay subsoil in response to weathering of the underlying shale, claystone or siltstone with the red podzols developing from material with an iron rich component. Shale outcropping and wide

benching is predominant in the Pheasants Creek catchment while sandstone outcropping is predominant in the Georges River catchment.

The following Land Units have been recognised within eastern and southern parts of the council planning area on the basis of geological and topographical features:

Land Unit 1 - Predominantly cleared plateau tops on Hawkesbury Sandstones with transitional passage beds of exposed shales and moderate slopes up to 5 degrees.

Land Unit 2 - Gully sides in rocky gorge terrain and along drainage lines on Hawkesbury Sandstones with joint controlled cliffed benches and steep slopes sometimes in excess of 25 degrees.

Land Unit 3 - Gully sides in rocky terrain on Hawkesbury Sandstones with extreme exposure of interbedded shales and a joint-controlled, stepped appearance.

The vegetation occurring in the study area on Land Unit 1 is predominantly woodland with Blue Stringybark *Eucalyptus agglomerata* and Red Bloodwood *Corymbia gummifera* as the dominant canopy species. Grey Gum *E. punctata* becomes dominant where interbedded lenses of shale occur but is replaced as the dominant canopy species by Blackbutt *E. pilularis* where sandstone predominates. Yellow earth soils occur in the south where the vegetation changes to one dominated by Hard-leaved Scribbly Gum *E. sclerophylla*, Red Bloodwood and Blue Stringybark. Understorey vegetation includes *Banksia spinulosa, Lambertia formosa* and *Leptospermum trinervium* on sandstones with *Kunzea ambiqua, Grevillea linearifolia, Dillwynia parvifolia* and *Acacia binervata* occuring mainly on shale areas.

Land Unit 2 comprises woodlands with Blackbutt and Smooth-barked Apple *Angophora costata* as the dominant canopy species. Narrow-leaved Apple *Angophora bakeri* occurs as a dominant lower stratum tree on some easterly aspects. Understorey vegetation is similar to that of Land Unit 1 on sandstones while *Grevillea mucronulata* becomes more dominant as moisture increases towards lower slopes.

The vegetation of Land Unit 3 includes wet heathlands under a woodland canopy of Sydney Peppermint *Eucalyptus piperita*, Smooth-barked Apple and Red Bloodwood, interspersed with pockets of the Whip-stick Mallee Ash *E. multicaulis*.

The Land Units in the western and north western parts of the council planning area include predominantly to almost totally cleared former eucalypt woodland and forest landscapes. These range from gently undulating rises and undulating to rolling hills on Wianamatta Group Shales, through gently undulating slopes on Tertiary and Quaternary floodplains and terraces of the Nepean River, to floodplains, river flats and drainage depressions in conjunction with incised channels on the Cumberland Plain.

2.0 METHODOLOGY

2.1 Assessment of Habitat Utilisation by koalas in the Study Area

Site Selection

The tree species preferences and other aspects of habitat utilisation by koalas in the study area were assessed using a plot based methodology developed by the Australian Koala Foundation for the purposes of the Koala Habitat Atlas Project (Sharp & Phillips, 1997; Phillips *et al*., submitted). To this end the study area was sub-divided into its respective geological units based on maps obtained from the Department of Mineral Resources. These areas were then overlain with a 1:25000 vegetation map, which was specifically prepared for the study. Potential field site localities were determined by arbitrarily selecting a discrete area of vegetation, the boundaries of which were delineated by those occurring on the vegetation map, but which could also be associated with a given geological unit (i.e. shale *vs* sandstone). Such areas were then partitioned using a 50m x 50m grid based numerical overlay. Independently generated random numbers were then used to determine final plot locations and the site co-ordinates for the centre of each grid cell so selected were then transferred to GPS units to assist their location in the field. A series of independent replicates for each of the identified vegetation communities occurring on each particular geological unit were also generated to facilitate the collection of statistically useful data on

the use of different tree species by koalas. Further aspects of the methodology, including details of the process by which sites are assessed, have been described elsewhere (Phillips *et al.*, submitted).

2.2 Vegetation Mapping

Accurate vegetation mapping was considered to be the most critical component of the data layers required for modelling purposes. Mr Robert Payne was subsequently engaged to prepare a vegetation map of the entire study area. Interpretation of 1:16000 (1992) stereo aerial photograph coverage was undertaken to identify and detail vegetation to structural level. Boundaries were marked up on the aerial photographs with the aid of a stereoscope and transferred onto 1:25000 topographic map sheets for use in the field.

The vegetation was described structurally according to the classification of Specht (1981) and floristically based on the style and classifications of Keith (1994) and the floristic standard of the National Herbarium of New South Wales. At a number of locations within each of the identified vegetation communities 20m square quadrat based descriptions were compiled and then combined to produce overall vegetation community descriptions. 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 National Herbarium of New South Wales. Intensive field survey and ground truthing of the vegetation mapping was undertaken during the course of koala habitat assessments for preparation the Koala Habitat Atlas.

2.3 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. The central reference 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 north-western quadrat. Data from each respective quadrat was recorded in corresponding columns of a specific Koala Habitat Atlas Site Recording Form.

The aspect (in degrees) from the approximate centre of each 20m X 20m quadrat was recorded and every tree that had a diameter at breast height (DBH) of 100mm or greater was marked with flagging tape which was 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 the Atlas 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. All faecal pellets falling within a circle of radius 100cm from any point at the base of each tree were counted and the total number recorded on the Site Recording Form. If the tree species identity was not known it was recorded as such but still assessed using the protocol prescribed by this methodology. However, flagging tape was not removed in order that the tree could be found again if necessary; 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.

The faecal pellet count was 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 person minutes were devoted to the faecal pellet search at each tree. Once counted and recorded, all pellets 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 total number of pellets within a 100cm radius of each tree were recorded independently.

2.4 Data Analysis

"Active" and "Non-Active" Sites

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 plot sites were initially divided into either "active" or "non-active" on the basis of whether faecal pellets were present (active) or absent (non-active). Only "active" plot sites from each of the major land units were considered for analysis purposes.

Faecal Pellet Counts, Activity Levels and Proportional Strike Rates

The median pellet score, range, mean, standard deviation and standard error associated with the faecal pellet counts were calculated from all trees in the study area which had one or more faecal pellets recorded beneath them and for both "eucalypt" and "non-eucalypt" categories.

For the purposes of subsequent analyses no further consideration was given to the total number of faecal pellets beneath any tree, rather they were considered to be either present or absent, thereby transforming the results into that being measured by a binary response variable. For each tree species, a proportional "strike rate" was determined based on the number of individual trees of a given species which had one or more Koala faecal pellets recorded beneath them, divided by the total number of trees of that species recorded in the respective plot.

Activity levels for each plot were expressed as a percentage equivalent of the quotient derived by dividing the total number of trees (of all species) which had one or more faecal pellets beneath them by the total number of trees (of all species) in the plot.

Tree Preferences and Habitat Utilisation

Following the procedures established by Phillips *et al*.(submitted) tree species preferences and habitat utilisation considerations were determined from a comparative analysis of the

results from all "active" plots. In this regard, it was originally intended that the data sets for each of the tree species would only be treated as valid for assessment purposes when the data set for a given species had been obtained from at least seven independent but otherwise "active" sites for a given geological strata. Data sets which satisfied the above criteria were to be considered as part of a primary data set comprised of those tree species which were being most frequently utilised by koalas in the study area and thus most likely to be of some importance in terms of sustaining the population.

Field based assessments quickly established that koala activity in the LGA was potentially quite localised. Initial site assessments followed by extensive vehicle and foot based traverses of the larger study area failed to detect evidence of koalas outside of that area immediately adjacent to and north of the Wedderburn Plateau. Further field work was subsequently concentrated in this area. Even within this area, evidence of koalas, specifically the presence of koala faecal pellets, was uncommon and the likelihood of gathering sufficient data on each of the tree species being utilised to the extent specified in the above criteria was considered poor. Because of this, sampling criteria (in terms of the minimum number of active sites required) were removed and the extent of variation amongst the strike rates for eucalypt and non-eucalypt data sets respectively were assessed using a Kruskal-Wallis Anova with the U statistic derived from Wilcoxon two sample tests used to test for evidence of significant differences in the levels of utilisation between species. Kendall's Robust line-fit method was used to examine the relationship between density (no. live stems/unit area) and the proportion of trees with pellets at each site for those tree species which were most preferred. A logarithmic transformation was applied to the proportional data and all non positive values were excluded for analysis purposes; density figures for each tree species were obtained directly from that recorded in the study plots.

All statistical analyses followed protocols and procedures detailed by Sokal & Rohlf (1995) and were largely undertaken using BIOMStat 3.2 & SPSS 6.1 software. The significance level used in all tests was 0.05.

2.5 Compilation of Attribute Layers for Modelling Purposes

Spatial data comprising discrete cell based maps relating to relevant physio-geographic and botanical components of the study area were compiled on Hewlett-Packard Apollo 9000 Workstations running Genamap 6.2 and related software. Data layers were geo-referenced to real world co-ordinates and rasterised to 25m pixels for analysis purposes. Habitat modelling was undertaken on the basis of density weighted attributes of the vegetation communities as determined from field based plots and from field notes accompanying the vegetation map, the former intersected with underlying soil landscapes and then modelled across the entire study area.

Attribute	Scale/Resolution	Source	Accuracy (estimate)
Geology	1:250000	DMR	80% (50-100m)
Soils	1:100000	LAWC	Unknown
Vegetation	1:25000	AKF	75-90%
DTM	n.a	AKF	10 metre
Contours	n.a	LIC	10 metre
Cadastre	n.a	LIC	Unknown
Drainage	n.a	LIC	10 metre
Cultural	n.a	LIC	10 metre

Table 1. Attribute layers assembled for modelling purposes (DMR = Dept. of Mineral Resources; LAWC = Dept. of Land and Water Conservation; AKF = Australian Koala Foundation; LIC = Land Information Centre; n.a = not applicable).

3.0 RESULTS

3.1 Koala Habitat Utilisation in the Study Area

A total of 2499 trees comprised of 1159 eucalypts and 1340 non-eucalypts from 45 field sites were assessed during the study. Evidence of tree use by koalas was obtained from 20 of the 45 field sites with faecal pellets recorded from beneath 7 species of *Eucalyptus* and from 6 species of non-eucalypt (Table 1). Activity levels of the 20 active sites ranged from 1.2% to 18.4% (mean = 6.0%). The mean activity level on sandstone derived substrates was

3.41% , whereas that for shale derived substrates was 9.0%. Activity levels on shale derived substrates were significantly higher than that of sandstone derived substrates ($t_{[18]} = -3.25$, $P < .01$).

Species	No. sites	n_i	P_i (%)	Species	No. sites	n_i	P_i (%)
Eucalypts				Non-eucalypts			
E. agglomerata^A	4	19	0.316	*Allocasuarina littoralis*^{A}	1	11	0.000
E. agglomerata^B	6	58	0.190	*A. littoralis*^{B}	2	17	0.000
E. capitellata^A	3	36	0.056	*Angophora bakeri*^{A}	1	18	0.056
E. capitellata^B	1	2	0.000	*A. costata*^{A}	7	42	0.024
E. consideniana^A	1	14	0.000	*A. costata*^{B}	11	76	0.013
E. multicaulis^A	2	33	0.000	*A. subvelutina*^{A}	1	3	0.000
E. multicaulis^B	1	3	0.000	*Banksia serrata*^{A}	6	54	0.000
E. paniculata^A	1	1	0.000	*B. serrata*^{B}	5	20	0.050
E. paniculata^B	1	3	0.000	*Corymbia gummifera*^{A}	9	177	0.006
E. pilularis^A	2	20	0.000	*C. gummifera*^{B}	10	221	0.050
E. pilularis^B	5	41	0.024	*C. eximius*^{B}	1	1	0.000
E. piperita^A	2	18	0.000	*Hakea sericea*^{B}	1	1	0.000
E. piperita^B	4	26	0.154	*Leptospermum attenuatum*^{A}	1	2	0.000
E. punctata^A	4	44	0.068	*L. attenuatum*^{B}	1	3	0.000
E. punctata^B	10	154	0.169	*Melaleuca hypericifolia*^{A}	4	7	0.000
E. sclerophylla^A	1	17	0.000	*M, hypericifolia*^{B}	4	12	0.083
E. sclerophylla^B	2	4	0.250	*M. linarifolia*^{A}	1	3	0.000
E. sieberi^A	2	20	0.050	*Persoonia pinifolia*^{A}	1	2	0.000
E. sieberi^B	2	3	0.333	*P. pinifolia*^{B}	1	1	0.000
				Syncarpia glomulifera^A	2	15	0.267
				S. glomulifera^B	4	28	0.036
Total Trees		**516**				**714**	

Table 2. Results obtained from 20 active sites in the Campbelltown LGA which had been utilised by koalas. Superscript "A" or "B" relates to underlying substrates derived from Sandstone or Shale respectively.

The extent of variation in the levels of utilisation amongst the seven species of eucalypt was significant across substrates (Kruskall-Wallis ANOVA: $H_{adj} = 14.919 > \chi^2_{.05[6]} = 12.592$). Details relating to a comparison of levels of utilisation between each of the seven species are provided in Table 2, the results of which indicate that *E. agglomerata* and *E. punctata* receive significantly higher levels of utilisation when compared to the other five species, with the possible exception of *E. sieberi* & *E. sclerophylla*. In common with the result obtained for *E. agglomerata*, the levels of utilisation for *E. sieberi* & *E. sclerophylla* also do not differ significantly from that of *E. punctata*, *E. capitellata* and *E. pilularis*. Examination of the data further suggests that the potential

affinity of *E. sieberi* & *E. sclerophylla* with both *E. agglomerata* and *E. punctata* is largely attributable to the results obtained from two independent sites where faecal pellets were recorded beneath one of only two specimens sampled in each case. This indicated a disproportionately higher level of use than that otherwise expected, a phenomena further compounded by the generally small sample size associated with these particular species in each instance.

Species	Ecap	Epil	Epip	Epun	Esie	Escl
Eagg	**34**	**60**	**48**	76	28	20
Ecap		18	15	**47.5**	8.5	6
Epil			22	**86**	19	13
Epip				**69**	16	11
Epun					38	27
Esie						6.5

Table 3. Critical values of the Mann-Whitney statistic "*U*" as they relate to between species comparisons across both geological strata for seven species of eucalypt utilised by koalas in the Campbelltown LGA (Eagg = *E. agglomerata*; Ecap = *E. capitellata*; Epil = *E. pilularis*; Epip = *E. piperita*; Epun = *E. punctata*; Esie = *E. sieberi,* Esc = *E. sclerophylla*). Comparisons which resulted in significant differences being detected are underlined and bolded.

The paucity of faecal pellet evidence generally precluded a detailed comparison of levels of utilisation for each of the six species between the two main geological strata present in the study area. *E. capitellata* was poorly represented on shale sites whereas *E. piperita* and *E. pilularis*, while present in a number of active sites, did not have koala faecal pellets observed beneath them. The following analyses are subsequently restricted to those species that were both commonly encountered and consistently associated with koala activity.

a) Hawkesbury Sandstones

Twenty-five sites were sampled. A total of 1,335 trees were assessed comprised of 12 species of eucalypt and 15 species of non-eucalypt. Nine of the 25 sites contained evidence of utilisation by koalas with faecal pellets recorded from beneath 4 species of

eucalypt (*E. agglomerata, E. capitellata, E. punctata* and *E. sieberi*) and 4 species of non-eucalypt (*Acacia bakeri, Angophora costata, Corymbia gummifera* and *Syncarpia glomulifera*). The extent of variation in the levels of utilisation amongst the four eucalypt species was not significant (Kruskall-Wallis ANOVA: $H_{adj} = 3.198 < \chi^2_{.05[3]} = 7.815$) .

b) Wianamatta Shales

Twenty sites were sampled. A total of 1,164 trees were assessed comprised of 12 species of eucalypt and 12 species of non-eucalypt. Eleven of the 20 plots provided evidence of use by koalas, with faecal pellets recorded from beneath 6 species of eucalypt and 4 species of non-eucalypt.

Useful data was restricted to four of the six eucalypt species beneath which faecal pellets were consistently recorded, that relating to *E. sieberi* and *E. sclerophylla* being excluded due to their poor representation (2 sites each) and small sample sizes (n= 3 & n = 4 respectively). The extent of variation in the levels of utilisation amongst the remaining four species was significant (Kruskall-Wallis ANOVA: $H_{adj} = 9.066 > \chi^2_{.05[3]} = 7.815$), the results of a comparison of levels of utilisation between each of the five species establishing that *E. punctata* was the most prefered. However, it was also evident that the levels of utilisation of *E. agglomerata* did not differ significantly from that of *E. punctata*, but nor did they differ significantly from that of the remaining species.

Species	Epil	Epip	Epun
Eagg	26	18	39
Epil		11	**47**
Epip			**34**

Table 4. Critical values of the Mann-Whitney statistic "*U*" as they relate to between species comparisons for four species of eucalypt utilised by koalas on shale based substrates in the Campbelltown LGA. (Eagg = *E. agglomerata*; Epil = *E. pilularis*; Epip = *E. piperita*; Epun = *E. punctata*). Comparisons which resulted in significant differences being detected are underlined and bolded.

Figures 2a & 2b illustrate the regression lines associated with the levels of utilisation of *E. punctata* and *E. agglomerata* as a function of changes in their respective densities. Both results suggest a tendency for levels of use to be negatively related to increases in density. While the trend appears to be most evident in *E. punctata,* the results in both instances were not determined as significant (*E. punctata*: z = -1.4044, P = 0.0801; *E. agglomerata*: z = -0.7746, P = 0.2193).

The Use of Non-eucalypts

Faecal pellets were recorded beneath six species of non-eucalypt (table 2). Analysis was restricted to five species, with that for *A. bakeri* excluded due to its representation in a single site. The extent of variation in the levels of utilisation for the remaining five species was not significant across substrates (Krusskal-Wallis ANOVA: $H_{adj} = 6.837 < \chi^2_{.05[4]} = 9.488$). However, when substrate based levels of utilisation were analysed there was significant variation on sandstone based substrates (Krusskal-Wallis ANOVA:- $H_{adj} = 15.211 > \chi^2_{.05[4]} = 9.488$). A between species comparison indicated that the heterogeneity was primarily associated with *Syncarpia glomulifera* (Table 5). Despite the presence of a more substantive *S. glomulifera* data set (n = 28 trees from 4 sites) there was no significant variation amongst the use of non eucalypts growing on shale based substrates (Krusskal-Wallis ANOVA: $H_{adj} = 4.745 < \chi^2_{.05[4]} = 9.488$).

Species	Bser	Mhyp	Sglo	Cgum
Acos	21	14	**12**	25.5
Bser		-	27	27
Mhyp			**8**	20
Sglo				**16**

Table 5. Critical values of the Mann-Whitney statistic "*U*" as they relate to between species comparisons for five species of non-eucalypt utilised by koalas on shale based substrates in the Campbelltown LGA. (Acos = *Angophora costata*; Bser = *Banksia serrata*; Mhyp = *Melaleuca hypericifolia*; Sglo = *Syncarpia glomulifera*; Cgum = *Corymbia gummifera*). Comparisons which resulted in significant differences being detected are underlined and bolded.

Inactive Sites

A total of 25 inactive sites were assessed during the course of field work. The sites were equitably distributed across both substrate types (table 6).

Species	No. sites	n_i	Species	No. sites	n_i
Eucalypts			Non-eucalypts		
E. agglomerata^A	12	55	*Allocasuarina littoralis*^{A}	2	21
E. agglomerata^B	6	60	*A. littoralis*^{B}	2	2
E. capitellata^A	1	7	*Angophora bakeri*^{A}	2	69
E. consideniana^A	1	2	*A. costata*^{A}	9	84
E. crebra^A	2	17	*A. costata*^{B}	2	16
E. crebra^B	1	2	*A. subvelutina*^{B}	3	13
E. fibrosa^B	1	1	*Banksia serrata*^{A}	7	29
E. mollucana^A	4	84	*B. serrata*^{B}	2	3
E. mollucana^B	1	2	*Casuarina cunninghamiana*^{A}	1	1
E. multicaulis^A	4	66	*Corymbia gummifera*^{A}	11	177
E. multicaulis^B	1	42	*C. gummifera*^{B}	8	108
E. paniculata^B	1	2	*C. eximius*^{A}	2	2
E. pilularis^A	2	33	*C. maculata*^{B}	2	31
E. pilularis^B	3	67	*Exocarpus cupressiformis*^{A}	1	5
E. piperita^A	7	16	*Hakea sericea*^{A}	1	2
E. punctata^A	8	41	*H. sericea*^{B}	2	2
E. punctata^B	6	83	*Melaleuca hypericifolia*^{A}	7	25
E. sclerophylla^A	1	7	*M, hypericifolia*^{B}	1	1
E. sclerophylla^B	3	15	*M. linarifolia*^{A}	1	4
E. sieberi^A	2	2	*Persoonia pinifolia*^{A}	6	14
E. sieberi^B	1	1	*Syncarpia glomulifera*^{A}	1	16
E. tereticornis^B	1	38	*S. glomulifera*^{B}	1	1
Total Trees		**643**			**626**

Table 6. Results obtained from 25 inactive sites in the Campbelltown LGA. Superscript "A" or "B" relates to underlying substrates derived from Sandstone or Shale respectively.

Remaining Geomorphological Units

Additional geomorphological units occur within the Campbelltown Local Government Area represented by floodplain landscapes, including the southern section of the Cumberland Plain in the far north and west. Koala habitat assessments in these areas were precluded by both the absence of any substantial areas of remnant vegetation and the lack of any evidence of koala presence or activity. While many of these areas were inspected,

the absence of koala faecal pellet evidence predicated against the establishment of field plots.

3.2 Vegetation Communities

The following vegetation communities were identified by Mr Robert Payne (Ecological Surveys & Management) for the Campbelltown Local Government Area. The mapped distribution for each of these communities is presented in Figure 3.

PLATEAU TOPS IN THE EASTERN SECTION

Woodland on Hawkesbury Sandstone

Structure: Open to very open cover of trees generally between 8 and 10 metres high but occasionally up 15 metres high. Understorey ranges between sparse to dense with a cover of lower trees, shrubs, monocotyledons, graminoids and grasses.

There are two distinct vegetation types present depending on whether the underlying strata is sandstone or shale.

Main Trees: Sandstones
Corymbia gummifera, E. sclerophylla, E. oblonga, E. agglomerata and *Angophora costata*. Sometimes *E. resinifera, E. consideniana, E. sieberi, E. punctata, E. multicaulis* and *Angophora bakeri*.

Shales
Eucalyptus punctata, Corymbia gummifera, E. oblonga, E. sclerophylla. Sometimes *E. racemosa, E. globoidea* and *Angophora bakeri*.

Remarks: On sandstones this community is very diverse but where shale intrudes *E. punctata* becomes dominant and the understorey becomes floristically and structurally less diverse.

Ironstone Heath on Hawkesbury Sandstone

Structure: Very open cover of trees up to 10 metres high with a dense understorey of lower trees and shrubs, but a mid dense to sparse cover of monocotyledons, graminoids and grasses.

Main Trees: *Eucalyptus sclerophylla* is dominant but sometimes *Corymbia gummifera*, *E. punctata* and *E. oblonga* occur.

Remarks: Areas were either burnt or were high impact shelling zones.

Sedgeland on Hawkesbury Sandstone

Structure: Dense cover of graminoids (sedges) and shrubs up to 0.5 metres high with occasional trees.

Main Trees: *Eucalyptus sclerophylla*.

Remarks: Very restricted in distribution within the boundaries of the City of Campbelltown and should be nominated as a conservation area to protect the receiving waters of Woronora Creek.

Mallee Heath

Structure: Dense stands of mallees up to 5 metres high with occasional lower trees, up to 2 metres high and a sparse cover of shrubs up to 0.5 metres high. The density of understorey cover correlates with the coverage of rocky outcrops.

Main Trees: *Eucalyptus luehmanniana* with *E. multicaulis* commonly present.

Remarks: *E. luehmanniana* is coded 2RC and the vegetation community is considered appropriate for conservation.

GULLIES AND CREEKS IN THE EASTERN SECTION

Eastern Gully Forest on Hawkesbury Sandstone

Structure: Open to very open cover of trees 20-25 metres high. Understorey varies from sparse to mid dense with a cover of lower trees, shrubs, monocotyledons, graminoids and ferns. Grasses generally absent.

Main Trees: *Angophora costata, Corymbia gummifera, E. agglomerata and E. piperita*. Occasionally, *E. punctata* and *E. sieberi* (mallee form).

Western Gully Forest on Hawkesbury Sandstone

Structure: Mid-dense to open cover of trees up to 30 metres high. Understorey generally with a mid-dense cover of lower trees, but a sparse cover of shrubs, ferns, herbs, graminoids, grasses and scramblers.

Main Trees: *E. pilularis, E. punctata, Corymbia gummifera, E. agglomerata.* At times *E. fibrosa* and *E. crebra, Angophora bakeri, A. costata* and *Syncarpia glomulifera.*

Remarks: *E. punctata* is very common but not always present.

Dry Rainforest

Structure: Trees with a closed canopy cover up to 10 metres high often with emergents up to 20 metres high. Understorey mostly absent.

Main Trees: *Syncarpia glomulifera*, *Eucalyptus punctata*, *Backhousia myrtifolia, Trochocarpa laurina*.

Remarks: The only area noted in the City Council area. Considered to have high conservation value for the area.

PLATEAU AND SLOPES IN THE WESTERN SECTION

Woodland on Wianamatta Shale, Slopes and Plateau

Structure: Trees up to 20 metres high but commonly 15 metres high with an open to very open canopy cover. Understorey sparse to mid dense with a cover of shrubs up to 1.5 metres high with lower trees up to 4 metres high and a cover of herbs, graminoids and grasses up to 0.25 metres high.

Main Trees: *Eucalyptus tereticornis, E. moluccana, E. crebra, E. fibrosa, E. punctata* and *Angophora floribunda*. Occasionally *E. racemosa*, *Corymbia maculata* and *Angophora bakeri* can be locally dominant.

Remarks: Almost every unit of this vegetation is disturbed. No areas in pristine condition could be located.

RIVERS AND CREEKS ON QUATERNARY ALLUVIUM

Open Woodland Along River Flats

Structure: Remnant riparian woodlands comprised of a very open canopy of trees up to 25 metres high. Understorey generally disturbed but comprises a lower tree, shrubs, herb, graminoid and fern layer.

Main Trees: *Eucalyptus saligna x E. botryoides*, *E. elata*, *E. viminalis*, *Angophora subvelutina* and *A. floribunda*.

Remarks: Most areas are heavily invaded with weeds especially *Tradescantia albiflora* and *Gleditsea triacanthos*. One specimen of *Eucalyptus benthamii* was located near the Menangle Bridge.

Woodland Along Smaller Creeks

Structure: Remnant riparian woodland with open cover of trees up to 10 metres high and a dense understorey of herbs, graminoids and herbs.

Main Trees: *Casuarina glauca*.

Remarks: Heavily invaded with weeds from previous pasture activities.

4.0 DISCUSSION

The results of this study support a model of habitat utilisation by koalas that is principally based on two species of eucalypt: Grey Gum *Eucalyptus punctata* and Blue-leaved Stringybark *Eucalyptus agglomerata*, both of which can be shown to be the subject of significant levels of utilisation by koalas in the study area. This is particularly the case for *E. punctata* when occurring in association with either shale benching or outcropping shale deposits including those on the plateau tops. The significance of both *E. punctata* and *E. agglomerata* on substrates derived from shales, as compared to that recorded for the same species on sandstones, indicates that their importance from a koala's perspective is strongly influenced by factors such as micro-changes in the level of soil nutrients. Notwithstanding issues associated with disease and the depredations of both motor vehicles and dogs on the koala population, the presence of these two tree species' and their occurrence in conjunction with relatively higher-nutrient substrates including those associated with shale outcrops must be considered to be the major limiting factors affecting the distribution and abundance of koalas in the study area. Evidence indicates that individual trees of the species subject to significant levels of utilisation become highly important in terms of koala habitat where they occur on what may be very localised areas of relatively higher-nutrient substrate. This apparent aspect of koala habitat utilisation may be supported by the research

findings of the CSIRO's Division of Wildlife and Ecology, Canberra which indicates that where the supply of nutrients is low, as in the case of low-nutrient soils, plants including eucalypts are likely to direct more energy to chemical defence than might be expected for plants growing on soils with higher-nutrient status (Cork & Braithwaite, 1996).

For the purposes of the Koala Habitat Atlas, the Australian Koala Foundation recognises the following four categories of koala habitat:

PRIMARY HABITAT

Floristic alliances and/or associations wherein primary food tree species for koalas comprise greater than or equal to 50% of the dominant overstorey tree species.

SECONDARY HABITAT (CLASS A)

Floristic alliances and/or associations wherein primary food tree species comprise less than 50% but generally greater than 30% of the dominant overstorey tree species; or

Floristic alliances and/or associations wherein primary food tree species together with secondary food tree species comprise greater than 30% of the dominant overstorey tree species; or

Floristic alliances and/or associations wherein secondary food tree species together with supplementary food tree species comprise 30% or greater of the dominant overstorey tree species (Primary Food tree absent).

SECONDARY HABITAT (CLASS B)

Floristic alliances and/or associations wherein primary food tree species alone comprise significantly less than 30% of the dominant overstorey tree species; or

Floristic alliances and/or associations wherein primary food tree species together with secondary food tree species comprise significantly less than 30% but generally greater than 10% of the dominant overstorey tree species; or

Floristic alliances and/or associations wherein the presence of secondary food tree species or secondary food tree species together with supplementary food tree species comprise less than 30% but greater than 10% of the dominant overstorey tree species (Primary Food tree absent).

MARGINAL HABITAT

Floristic alliances and/or associations wherein secondary food trees alone or secondary food trees together with supplementary food tree species comprise less than 10% of the dominant overstorey tree species (Primary Food tree absent).

** All figures above relate to average values derived from independently sampled field sites.*

UNKNOWN HABITAT VALUE

Recognisable floristic alliances and/or associations containing tree species considered likely to be the subject of significant levels of utilisation by koalas but whose value cannot be quantified due to an absence of activity indicators most likely associated with localised extinction events.

Food Tree Categories

Primary Food Tree

A tree species which generally returns a significantly higher "strike rate" of 50% or greater and which demonstrates a level of use which can be shown to remain constant in response to changes in density.

Secondary Food Tree

A tree species which generally returns a "strike rate" of less than 50% but which, in the absence of a primary food tree species, is significantly higher when compared to other congeners, and which demonstrates a level of utilisation which is density dependent.

Supplementary Food Tree

A tree species which similarly returns a strike rate which is generally less than 50% but which cannot be isolated as the subject of significantly higher levels of utilisation when compared to other congeners, but which similarly demonstrates a density dependent level of utilisation.

** Percentile values provided above are based on the results of analyses undertaken on a pooled sample which has been derived from a series of independent sites sharing similar geological attributes such as soil type.*

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.

The Significance of Activity Indicators

The association between the presence of Grey Gum *Eucalyptus punctata* and Blue-leaved Stringybark *Eucalyptus agglomerata* and the relatively higher koala activity levels supports a contention that the higher utilisation rates recorded for koalas in these areas are primarily due to the presence of these particular species. However, significant levels of activity may also extend into adjoining areas of Marginal Koala Habitat. Such instances are likely to be less of a reflection on the nutritional value of the Marginal Habitat than their proximity to the significant tree species, but in this regard they must be considered an important habitat component from the koalas perspective, providing secure roosting and interaction areas and opportunistic browsing opportunities.

The lack of any obvious koala activity in the western parts of the study area may be a result of widespread localised extinctions. Historical research would be required to determine the likely historical distribution and historical habitat utilisation of koalas within the Campbelltown Local Government Area, particularly in western areas which have been subjected to extensive vegetation clearing, disturbance and fragmentation. Nonetheless, it is considered likely that koalas historically inhabited once forested areas on the Wianamatta Shale and Cumberland Plain landscapes of the far north and west of Campbelltown LGA.

The Koala Habitat Atlas project was unable to determine the level of significance of Forest Red Gum *E. tereticornis* for the koala population within the Campbelltown LGA. However, research undertaken by the AKF in other areas of NSW has identified *E. tereticornis* as a species subject to preferentially utilisation by koalas. Future investigation into the present occurrence and distribution of Forest Red Gum *E. tereticornis* within identified 'Woodland on Wianamatta Shale' communities will allow areas where the species is a principal component to be incorporated into the 'Unknown Koala Habitat' category. Historical research may provide evidence to justify the eventual incorporation of such areas into known koala habitat categories, potentially including the Primary Habitat category.

Given the low density of the remaining koala population within the Campbelltown Local Government Area it is recommended that any koala faecal pellet evidence should be considered significant in terms of the potential importance of that site for koalas.

Campbelltown Koala Habitat Atlas Modelling

Generation of the Campbelltown Koala Habitat Atlas required the incorporation of digital data layers including elevation and terrain, geology, soil landscapes, vegetation, drainage, land tenure and cultural features, with koala habitat modelling reliant particularly on vegetation and soil landscapes in conjunction with results from habitat assessments.

The modelling of Secondary Koala Habitat (Class A) within the Campbelltown City Council planning area involved vegetation associations where Grey Gum *E. punctata* and

Blue-leaved Stringybark *E. agglomerata,* are dominant components of the overstorey intersected with areas of Wianamatta Group shale derived soil landscapes. Secondary Koala Habitat (Class B) includes vegetation associations where Grey Gum *E. punctata* and Blue-leaved Stringybark *E. agglomerata,* are either sub-dominant components of the overstorey intersected with areas of Wianamatta Group shale derived soil landscapes or dominant components of the overstorey occurring on soil landscapes other than those derived from shale (principally Hawkesbury Sandstones). Marginal Koala Habitat includes remaining areas of vegetation, other than areas of 'Unknown' Koala habitat value, where Grey Gum *E. punctata* and Blue-leaved Stringybark *E. agglomerata* may occur at low densities (generally less than 10%), irrespective of the soil landscape (see Figure 4 - Campbelltown Koala Habitat Atlas).

Densities for Grey Gum *E. punctata* and Blue-leaved Stringybark *E. agglomerata* were determined on the basis of data from Atlas plot assessments together with descriptions for each of the identified floristic associations provided in the vegetation mapping report prepared by Mr Robert Payne of Ecological Surveys & Management.

HABITAT DESCRIPTIONS

Secondary Koala Habitat (Class A)

Secondary Koala Habitat (Class A) within the LGA constitutes approximately 2,264.7 hectares and includes those vegetation communities containing Blue-leaved Stringybark *Eucalyptus agglomerata* and/or Grey Gum *Eucalyptus punctata* growing on substrates derived from outcropping shale (both on bench formations and on plateau tops). This habitat category supports relatively high densities of either or both *E. punctata* and *E. agglomerata*; combined Mean = 50 % $\pm$ 6.6 %; n = 7 sites; range = 30-71 %.

Secondary Koala Habitat (Class B)

Secondary Koala Habitat (Class B) within the Campbelltown Local Government Area constitutes approximately 2,360.7 hectares and includes those vegetation communities containing Blue-leaved Stringybark *Eucalyptus agglomerata* and/or Grey Gum *Eucalyptus punctata,* growing on substrates derived principally from sandstone, often with localised shale influence (including steep-sided gullies, gully bottoms and plateau tops). This habitat category generally contains lower densities of either or both *E. punctata* and *E. agglomerata* (relative to Secondary Koala Habitat-Class A); combined – Mean = 20 % $\pm$1.5 %; n = 8 sites; range = 13-26 %.

Marginal Koala Habitat

Marginal Koala Habitat within the Campbelltown Local Government Area constitutes approximately 11,222.1 hectares and consists of those remaining forested or wooded vegetation communities not otherwise identified as either Secondary Koala Habitat (Class A or Class B) growing on substrates derived principally from sandstone, occasionally with localised shale influence. This habitat category generally only contains very low densities of Blue-leaved Stringybark *Eucalyptus agglomerata* with some localised and very low densities of Grey Gum *E. punctata*; both species are often totally absent.

Unknown Koala Habitat Value

Areas identified as 'Unknown Koala Habitat' within the Campbelltown Local Government Area constitute approximately 109.4 hectares and consist of 'Open Woodland' occurring on Quaternary alluvium along river flats. This community includes *Eucalyptus saligna X E. botryoides*, *E. elata*, *E. viminalis*, *Angophora subvelutina* and *A. floribunda* as the main tree species present and is considered to be of potential although as yet unquantified significance as koala habitat due to an absence of activity indicators, possibly associated with localised extinctions.

Distribution and Status of the Campbelltown Koala Population

Those habitat categories with the greatest potential for effective long term conservation and management of the Campbelltown koala population include Secondary (Class A) and Secondary (Class B) habitat which collectively comprise 4,625.4 hectares or approximately 29 % of the remaining forested areas within the Local Government Area. Field research has indicated that this habitat either contains populations at very low densities or is not being currently utilised by koalas. This contention is supported by the generally low activity levels recorded during field research, the proportion of inactive sites which contain Blue-leaved Stringybark *Eucalyptus agglomerata* and/or Grey Gum *Eucalyptus punctata* and the extensive foot based traverses conducted in these areas.

While the extent to which the low koala population density has been influenced by historical land use practices or threatening processes remains uncertain, it is likely to be at least in part a reflection of habitat quality and/or carrying capacity, with low activity levels and relatively large home range areas arguably consistent with that expected for koala habitat utilisation in low nutrient environments. Historical research may provide evidence to confirm a suspected range contraction by the koala population of the study area over the last 100 years (or more) to the extent that remaining populations may now largely be confined to sub-optimal koala habitat.

Using qualitative criteria, Close (1993) suggested a density of 0.1koalas/ha in the Wedderburn area. Elsewhere, research conducted on two low density koala populations occupying woodland habitat on low fertility soils in Central Queensland by Melzer and Lamb (1994) established population densities of one animal per 67 hectares and one animal per 210 hectares respectively. While the actual size and status of the current koala population for the Campbelltown Local Government Area remains speculative, calculations on the basis of the total available Secondary (Class A) and Secondary (Class B) Koala Habitat identified by the Koala Habitat Atlas in conjunction with the above density data result in an estimated Koala population in the study area of between 30 and 90 individuals.

In order to view the population estimate in an appropriate context some consideration must also 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 koalas perspective suggest an "effective" population size in the study area of between 10 and 30 individuals (figures based on a 50:50 sex ratio at birth, a polygynous social structures with a strong female bias and 35% infertility) which would already fall close to or below the minimum required for likely medium to long term survivorship (Friend, 1990).

Given the degree of geographic isolation from other known koala populations and the subsequent 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 Campbelltown Local Government Area should be considered endangered and under threat of localised 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 Koala Plans of Management for their respective Local Government Areas in accordance with set guidelines. These guidelines are currently under review as are the relevant schedules of the State Environmental Planning Policy including the schedule identifying the Local Government Areas where the policy applies and the schedule of Koala Feed Tree Species.

In this regard the Campbelltown Local Government Area was not included on the initial list of Local Government Areas where the policy applies despite the presence of an extant koala population. Additionally, areas of important koala habitat recognised for the purposes of the Habitat Atlas are inconsistent with those which otherwise would have resulted with the stringent application of current SEPP No. 44 criteria in terms of the scheduled Koala Feed Tree species. In particular, Blue-leaved Stringybark *Eucalyptus agglomerata* was identified by the Koala Habitat Atlas as a significant resource for koalas in the Campbelltown Local Government Area but has not been recognised as such by the SEPP for the purposes of identifying "potential koala habitat".

Notwithstanding the above, all areas of Secondary Koala Habitat (Class A and Class B) as defined by the Koala Habitat Atlas could potentially constitute "Core" koala habitat in accordance with SEPP No. 44.

Limitations of the Atlas Model

A comparison of results from completed Atlas field sites with the vegetation map established an initial accuracy measure of approximately 80%, with 34 of the 42 point samples provided by atlas plots within the Council area conforming to the vegetation communities delineated for those areas regardless of considerations associated with potential GPS inaccuracies. Subsequent ground truthing and refinement of the vegetation map suggests that at least
80-90% accuracy has been achieved.

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 Campbelltown City Council planning area:

1. Amend Campbelltown Local Environmental Planning documents to reflect the location and significance of identified Secondary (Class A and Class B) and 'Unknown' 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 Secondary (Class A and Class B) 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 (search procedures undertaken in accordance with Phillips & Callaghan, 1995 - the presence of any koala faecal pellets should be considered significant for the Campbelltown area irrespective of relative activity levels.

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 Secondary Koala Habitat (Class A or Class B) and/or individual Blue-leaved Stringybark *Eucalyptus agglomerata* or Grey Gum *Eucalyptus punctata* 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 Campbelltown City Council Local Government Area:

Grey Gum	***Eucalyptus punctata***
Blue-leaved Stringybark	***Eucalyptus agglomerata***

5. Modify existing Bushfire Management Plans and/or strategies to reflect the presence of known koala habitat and 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 all areas of Secondary 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 Secondary Koala Habitat on a minimum 5 year cycle.

6. Develop koala management strategies for specific areas including Kentlyn as well as other areas on the urban fringe 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 dog attrition, 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 Secondary Koala Habitat areas and adjacent lands.

8. Actively encourage community based reporting of koala sightings including females with joeys from within the LGA with a view to indentifying and monitoring possible locations of remaining breeding aggregations. Consistent with the requirements of SEPP 44, compile and maintain a central register for community based records of past and current koala distribution within the LGA.

9. Initiate an historical research program to determine the historical distribution of koalas within the Campbelltown Local Government Area. This should include the now predominantly cleared western sections and areas identified as 'Unknown' Koala Habitat.

10. 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.

11. Seek to establish Conservation Agreements for areas of 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 Secondary and Marginal Koala Habitat as designated by the Koala Habitat Atlas:

Secondary Habitat ***(Class A)*** : No further development should be approved within remaining areas of Secondary (Class A) 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 existing vegetation communities and/or individual Blue-leaved Stringybark *Eucalyptus agglomerata* or Grey Gum *Eucalyptus punctata* trees.

Secondary Habitat ***(Class B)*** : ***i)*** **New Urban Developments-Urban Development Program (as a condition of Development Consent)**

a) identify individual trees or clusters of trees known to be important to koalas in the area, including a stadia survey showing the locations and taxonomic identity of all Blue-leaved Stringybark *Eucalyptus agglomerata* and/or Grey Gum *Eucalyptus punctata* trees;

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 Blue-leaved Stringybark *Eucalyptus agglomerata* or Grey Gum *Eucalyptus punctata* tree 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 through measures such as those recommended by the Wedderburn Fauna Planning Study (Phillips, Callaghan, Parnaby and Fitzgerald, 1996), 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 Campbelltown City 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).

Existing Urban Developments

a) identify, delineate and protect areas of significant koala habitat including individual trees or clusters of Blue-leaved Stringybark *Eucalyptus agglomerata* and/or Grey Gum *Eucalyptus punctata* 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 supported by appropriate research.

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