Koala Habitat Atlas

Project No. 4 : Tweed Coast

DRAFT

Prepared for Tweed Shire Council

by

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EXECUTIVE SUMMARY

An assessment of tree preferences and habitat utilisation by Koalas was conducted in the Coastal section of the Tweed Local Government Area between February of 1994 and May of 1996. A total of 3,277 trees comprised of 1,885 eucalypts and 1,392 non-eucalypts from 52 primary plots and 18 supplementary quadrats were assessed during the study.

Tree species preferences from a Koala's perspective were determined on the basis of a comparative analysis of the summed proportional strike rates for each of eighteen tree species found to be commonly utilised by Koalas in the study area, according to respective occurrences on each of the main geomorphological units recognised for the purposes of the study. The results have established that three species of eucalypt, Swamp Mahogany *Eucalyptus robusta*, Tallowwood *Eucalyptus microcorys,* Forest Red Gum *Eucalyptus tereticornis* and the naturally occurring hybrid, *E. robusta* X *E. tereticornis* are the subject of preferential utilisation by Koalas within the study area. The occurrence of these eucalypt species appear to be the major natural limiting factors affecting the distribution, abundance and autecology of remaining populations of Koalas inhabiting the study area. The use of other species of eucalypt and non-eucalypt can be shown to be a phenomena associated with the presence of either one or more of the preferentially selected eucalypt species.

The Koala Habitat Atlas for the coastal section of the Tweed Local Government Area identified a total of 956.6 hectares of Primary Koala Habitat; 4,043.2 hectares of Secondary Koala Habitat-Class A; 3,862.2 hectares of Secondary Koala Habitat-Class B; and 252.8 hectares of 'Unknown' Koala Habitat. Together these categories of Koala habitat constitute a total area of 9,114.8 hectares or approximately 24.2 % of the 37,608.1 hectare study area. Approximately 66.2 % of the study area has already been cleared of native vegetation.

Further historical research may provide evidence to confirm a suspected significant range contraction by the Koala population in study area in conjunction with habitat clearing over the last 100 years.

Based on a considered but speculative estimate of the total population for the study area of between 200 and 300 individuals, which are extensibly geographically divided and often predominantly genetically isolated within relatively small breeding aggregations or sub-populations, the "effective" population size of many largely independent aggregations is already below the minimum required to afford the population a guaranteed level of medium term longevity, particularly given the potential consequences associated with factors such as 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 long term prognosis for the population is considered to be poor.

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 are numerous and include wildfire, the ongoing loss of habitat for residential expansion, agriculture, 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 the further destruction and modification of Primary and Secondary (Class A) Habitat areas known to be supporting koala populations, the recognition and establishment of urban koala management zones with appropriate controls on motor vehicle speeds and the keeping of domestic dogs, and the provision of legal sureties to enforce proposed Tree Preservation Orders and Covenants. Reviews of the existing Local Environmental Planning documents and Development Control Plans relating to current and proposed residential developments in the study area are also advocated.

1.0 INTRODUCTION

1.1 Habitat Utilisation by Koalas

The Koala *Phascolarctos cinereus* is an obligate folivore which feeds primarily on the genus *Eucalyptus*. Throughout its range in eastern and south-eastern Australia, the species has 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 from one to three species of eucalypt will be regularly utilised (primary use trees) 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, 1992).

In a socially stable population, individual Koalas have overlapping home range areas. Within each animal's 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 local Koala welfare groups further 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 Koala'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 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 movements in excess of 40-50km (Phillips, unpub data). Breeding activity usually initiates the dispersal phase of 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 endemic 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 activities such as logging and sand mining can be shown to be having a significant impact on Koala populations, particularly where 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. In reality, the 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; Phillips, 1991). 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 incidentally recorded 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.

1.2 Description of the Study Area

Location

This report relates to a study of Koalas and their habitat in the coastal section of the Tweed Local Government Area, approximately 900 kilometres north of Sydney on the far north coast of New South Wales (Figure 1). The study area falls within the latitudes 28^0 9' and 28^0 30' south and longitudes 153^0 20' and 153^0 36' east. The 37,608 hectare study area is bounded by the Pacific Highway to the south-west, by Murwillumbah and the Tweed River to Tumbulgum in the west, then north to the New South Wales-Queensland border and east to the coast. The study area includes the towns and townships of Tweed Heads, Bilambil, Terranora, Banora Point, Fingal, Cobaki, Piggabeen, Condong, Cudgen, Duranbah, Chinderah, Kingscliff, Bogangar, Hastings Point, Clothiers Creek, Fernvale, Palmvale, Mooball, Pottsville, and Wooyung, as well as Mooball State Forest, Stotts Island Nature Reserve, Ukerebagh Nature Reserve, South Tweed Heads Historic Site, and the recently declared Round Mountain-Cudgen Lake Nature Reserve.

Climatic Conditions

Total annual rainfall in the Tweed area over the last 30 year period averaged 1,855 mm as recorded at the Bray Park Weather Station, and ranged from 846 mm in 1986 to 2,872 mm in 1974. While rainfall can occur throughout the year, most falls between January and April. Average monthly rainfall over the last 30 years ranged from a low of 13 mm for September to a high of 233 mm for March. The total annual number of days when rain was recorded at the Bray Park Weather Station over the last five years ranged from 125 days in 1991 to 152 days in 1993, with an average over that period of 142 days per year. Average annual temperatures in the Tweed typically range from a low of around 2^o C in winter to a high in the mid thirties during the summer months. Peak daily temperatures with a minimum of around 18^o C and a maximum of around 40^o C tend to occur from December to February, while lowest daily temperatures with a minimum of around 0 ^{o} C and a maximum of around 27 ^{o} C tend to occur from June to August.

Topography and Geomorphology

The geomorphology of the Tweed valley is dominated by the remains of the Mount Warning shield volcano with the eroded Mount Warning central core now approximately 1157 metres high. The remnants of the outer shield include the Nightcap Range to the south, the Tweed Range to the west and the MacPherson Range to the north.

The geology of the Tweed Local Government Area (LGA) is predominantly Palaeozoic and Mesozoic sediments overlain by Tertiary basaltic and rhyolitic flows from the Mount Warning Shield Volcano. The volcanic layers have now been largely eroded away by the Tweed River system exposing the underlying sedimentary rocks (Forestry Commission of NSW, 1984).

The geology of the coastal section of the Tweed LGA (the study area) includes greywacke, slate, phyllite and quartzite of the Neranleigh-Fernvale Group metamorphics, which predominate across the erosional upland landscapes of the study area; river gravels, alluvium, sands and clay of Quaternary/Pleistocene origin on the floodplains and depressions; Quaternary beach and dune sands along the coastal strip; and localised areas of remnant basaltic material associated with the Lamington Volcanics in the Terranora, North Tumbulgum, Cudgen, Clothiers Creek and Farrants Hill areas.

Vegetation

The following descriptions have been extracted from the "Report on Vegetation Mapping in Tweed Shire" prepared for the Australian Koala Foundation in conjunction with the Koala Habitat Atlas Project by Landmark Ecological Services Pty Ltd (1996).

"The mountain ranges and foothills were originally covered by mixed eucalypt forest and woodland with Brushbox *Lophostemon confertus* and rainforest occurring in sheltered, less fire-prone areas. The foothills are now mostly cleared but the ranges contain remnants of the original forest and some substantial areas of regrowth forest. The low-lying coastal plain and floodplain of the Tweed River was originally covered by a mosaic of swamp schlerophyll forest, subtropical and littoral rainforest and a coastal sclerophyll complex of heathland and sclerophyll woodland and forest. Virtually all the floodplain has now been cleared for cane growing or cattle grazing, with Stotts Island the only substantial remnant of these once impressive forests. The basalt plateau to the north-west of Cudgen Lake has also been cleared for agriculture with little of the original vegetation remaining." (Landmark Ecological Services Pty Ltd, 1996)

Landmark Ecological Services Pty Ltd (1996) report that the Burringbar Range, in the south-western section of the study area, contains the largest continuous area of forest that remains within eastern part of the Tweed LGA. This area also includes scattered patches of old-growth forest and contains highly significant stands of threatened plant and ROTAP species, such as *Davidsonia pruriens, Davidsonia sp. nov*. and *Endiandra floydii*. (Landmark Ecological Services Pty Ltd, 1996)

1.3 Study Objectives

The Australian Koala Foundation has undertaken this study for the Tweed Council in accordance with the specific objectives outlined below:

a) to quantify tree preferences and habitat utilisation;
b) to delineate areas of Primary and Secondary Koala Habitat;
c) to examine the relationship of this information in terms of SEPP No. 44;
d) to identify threatening processes; and
e) to recommend measures to provide Koala populations with a measure of long term viability.

2.0 METHODOLOGY

2.1 Assessment of Habitat Utilisation by Koalas in the Study Area

Habitat utilisation and tree preferences of 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. Plot selection in accordance with the methodology is stratified and essentially random but 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 corresponding data sets are compiled for each tree species; this latter consideration in particular inevitably leads to the introduction of some bias as sampling proceeds over the longer term.

2.2 Site Selection

Within each floristic boundary, plot site localities were determined using a 50m grid based numerical overlay with independently generated random numbers used to determine plot location. The resulting site co-ordinates were then transferred to GPS units to assist their location in the field. Independent replicates for each of the identified vegetation associations occurring on each particular geomorphological unit were also generated to permit statistical analysis of the results.

Statistical validation of data sets requires a minimum data set for each tree species, a consideration which further influences the number of required plot sites, dependent upon the density of that species within plots targeted to sample that species. 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, field plots were excluded from sites adjacent to major habitat disturbances such as recent bushfire, urban development and/or major roads.

2.3 Assessment of Field Sites

Once located in the field, establishment of each 40m x 40m primary field site involved using a compass, measuring tape and flagging tape to designate the corners of four 20m by 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. Supplementary field sites, normally in the form of a circle with a minimum radius of 10m, were also employed to gather additional data using the criteria of Phillips and Callaghan (1995).

The aspect (in degrees) from the approximate centre of each 20m X 20m quadrat was recorded and every tree with a diameter at breast height (DBH) of 100mm or greater was marked with flagging tape to be 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 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 carefully inspected for the presence of Koala faecal pellets. All Koala 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. 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 plant's 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 the 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 plots were initially categorised as either "active" or "non-active" sites on the basis of whether koala faecal pellets were present (active) or absent (non-active). Only "active" plots from each of the major geomorphological units were considered for analysis purposes.

Faecal Pellet Counts, Strike Rates and Activity Levels

The range, mean, standard deviation and median score 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 enumerative data. For each tree species a proportional "strike rate" was determined based on the number of individual trees 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. Strike rates for each species were then summed for each active plot and pooled for each of the geomorphological units being assessed.

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

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 within a given geomorphological/floristic unit were only regarded as valid for assessment purposes when:

a) the data set had been obtained from at least 7 independent but otherwise "active" sites;

b) np (the number of trees of a particular species multiplied by the proportion of those trees observed with one or more faecal pellets beneath them) and $n(1-p)$ were both at least as large as 5; and

c) the calculation of 95% Confidence Limits for the estimate were between 1% and 20% of the sample estimate so obtained, the level of rigour being determined by the estimated strike rate for the species being assessed (Figure 2).

Figure 2. Level of sampling rigour (upper bar equals plus/minus 20%, 10%, 1%) applied in response to variable strike rates and the extent to which they deviate from the normal approximation.

Analyses of the results from field work involved both parametric and non-parametric procedures. Due to differences in sample size, the extent of variation amongst the ranked strike rates for eucalypt and non-eucalypt data sets respectively were assessed using

Krusskal-Wallis 1-way Anova's with the *Z* statistic derived from one-tailed Mann Whitney U - Wilcoxon Rank-sum Tests used to test indications of preferential utilisation between species. Chi-square tests were used to test for significant differences between the summed proportional strike rate for each species on a plot by plot basis, strike rates for each species being pooled whenever the expected frequency (F) in any given plot was less than 5; continuity corrections were applied in all cases where one degree of freedom resulted from aspects of the analytical process.

The potential for relationships to exist between the levels of use by Koalas and the density of tree species subsequently shown to be the subject of preferential utilisation were examined in the first instance by Spearman's Rank Correlation Procedure, with evidence of significant relationships further examined using selected components of multiple regression analysis. T-tests were also utilised to examine *post hoc* relationships between activity levels and the presence of tree species subsequently determined by those procedures detailed above to be the subject of preferentially utilisation by koalas.

All statistical analyses utilised followed protocols and procedures detailed by Dunn (1964), Bhattacharya & Johnson (1977) and Berenson *et al* (1988) and were largely undertaken using SPSS 6.1 software.

2.5 Compilation of Attribute Layers for Modelling Purposes

Spatial data comprising vector based and discrete cell maps relating to relevant physio-geographic and botanical components of the study area were compiled on Hewlett Packard Apollo 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 parameters were defined on the basis of density weighted attributes relating to the presence of the preferentially utilised tree species within their associated communities, the latter determined from data derived from the field based plots and from field notes accompanying the vegetation map. These attributes were then intersected with underlying soil landscape data and associated geological attributes which were then modelled across the entire study area.

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

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

2.6 Vegetation Mapping

Accurate vegetation mapping was considered to be the most critical component of the data layers required for modelling purposes. Earlier field work was reliant upon vegetation maps for the Department of Planning. However, these maps were found to be floristically inaccurate and without a comprehensive coverage of the study area. Consequently, Landmark Ecological Services, the Australian Koala Foundation and Mr Robert Payne of Ecological Surveys & Management subsequently prepared a new vegetation map of the entire study area (Figure 3). To this end interpretation of 1:25,000 stereo aerial photograph coverage (1991) was undertaken to identify and detail vegetation to structural level with boundaries transferred onto 1:25,000 maps then ground-truthed on the basis of vegetation sampling sites prior to digitising. Mapping was further complicated by significant photogrammetry problems in some areas.

The vegetation was described structurally according to the classification derived by Walker and Hopkins (1990) from Specht *et al.* (1974) and the floristic standard of the

National Herbarium of New South Wales at a selected number of locations. Nomenclature followed Harden (1990, 1991, 1992 & 1993). Within each structural type, 20m square quadrats were used to collect detail for vegetation descriptions with the most commonly occurring plant species 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. Field survey and ground truthing of the mapping was conducted between February, 1996 and May, 1996. The following two site types were selected for recording detailed vegetation descriptions:

Major sites were located within large, relatively homogeneous vegetation patches and comprised an area of 0.283 ha (circle of 30 m radius). A description was taken of the canopy species composition within this area, with species listed in order of decreasing abundance. Dominant plant species in the mid and ground strata, the broad vegetation structure and the presence of mature and senescent trees were also noted.

Minor sites were located wherever substantial changes in canopy species composition (changes in vegetation associations) were observed and in small patches or linear strips of vegetation. The size of minor sites varied, depending on the size of the patch, but equalled the area of major sites where possible. The canopy species composition, with species listed in order of decreasing abundance, broad vegetation structure and the presence of senescent trees was recorded. The description of canopy species for minor sites varied from a full listing to restriction to dominant species.

3.0 RESULTS

3.1 Koala Habitat Utilisation in the Study Area

A total of 3,277 trees comprised of 1,885 eucalypts and 1,392 non-eucalypts from 52 primary plots and 18 supplementary quadrats (70 sites in total) were assessed during the study. Figure 4 shows the field survey site locations. Results are presented on the basis of the identified major geomorphological units.

a) Neranleigh-Fernvale Group Metamorphics

A total of 36 primary plot sites and 9 supplementary quadrats were sampled from Neranleigh-Fernvale Group geomorphological units. A total of 1,945 trees were assessed including 14 species of eucalypt (1,466 individual trees), with Northern Grey Ironbark *E. siderophloia* and Grey Ironbark *E. paniculata* treated as the same species for the purposes of data analyses, and 9 species of non-eucalypt (479 individual trees). Thirty of the 45 sites sampled contained evidence of utilisation by Koalas, with faecal pellets recorded from beneath 11 species of eucalypt and 5 species of non-eucalypt (Tables 1 and 2 of Appendix).

The total number of trees with one or more Koala faecal pellets recorded beneath them collectively comprised 146 of the 1,466 eucalypts and 26 of the 479 non-eucalypts assessed. The number of Koala faecal pellets recorded beneath eucalypts ranged between 1 and 11 while the number of Koala faecal pellets recorded beneath non-eucalypts ranged between 1 and 5. There was no significant difference between the average number of Koala faecal pellets found beneath eucalypts and those found beneath non-eucalypts. The highest faecal pellet count was recorded beneath an *Eucalyptus microcorys* at Site T051 (n=11).

Valid data sets were obtained for 8 of the 11 eucalypt species found to be commonly utilised by Koalas (White Mahogany *Eucalyptus acmenoides*, Red Bloodwood *E. gummifera,* Tallowwood *E. microcorys,* Blackbutt *E. pilularis,* Grey Gum *E. propinqua,* Red Mahogany *E. resinifera,* Pink Bloodwood *E. intermedia,* Northern Grey Ironbark *E. siderophloia/* Grey Ironbark *E. paniculata)* and for 2 of the 5 non-eucalypt species (Forest

Oak *Allocasuarina torulosa* and Brush Box *Lophostemon confertus*) beneath which Koala faecal pellets were recorded (Table 4).

Activity levels of the 33 "active" sites sampled on the Neranleigh-Fernvale Group geomorphological unit ranged from 0.8 **%** to 50 % (Mean = 13.1 %, Standard Deviation = 11.9 %, n=33). The highest activity level of 50 % was recorded for site T051 which comprised *Eucalyptus microcorys, E. propinqua, E. pilularis, E. intermedia, E. crebra, Lophostemon confertus and Allocasuarina torulosa*.

Krusskal-Wallis 1-way Anova's established that there were significant differences in the summed proportional strike rates on a species by species basis for eucalypt species (Chi-Square = 12.9876, 7df, p= .0724).

While *E. microcorys* had the highest mean proportional strike rate, Mann Whitney U - Wilcoxon Rank-sum Tests established that there was no significant difference between the strike rate for this species and that recorded for either *E. propinqua* (0.33 vs 0.29 : z= .436) or *E. resinifera* (0.33 vs 0.22 : z= .882). A significant difference was recorded between the strike rates for *E. microcorys* and all of the other eucalypt species (Table2). Although the strike rate recorded for *E. propinqua* does not differ significantly from that recorded for *E. resinifera* and *E. microcorys*, unlike the latter, it *does not differ significantly* from that recorded for all the other eucalypts including *E. acmenoides* (0.29 vs 0.06 : z= .832); E. gummifera (0.29 vs 0.18 : z= 1.067) and *E. pilularis* (0.29 vs 0.10 : z= 1.290). The strike rate for *E. resinifera* did not differ significantly from that of any of the eucalypt species recorded on the Neranleigh-Fernvale Group geomorphological unit.

	Eacm	***Egum***	***Eint***	***Emic***	***Esid***	***Epil***	***Epro***	***Eres***
Eacm	-	0.156	0.970	**1.976^**	0.540	0.307	0.832	0.912
Egum		-	0.732	**1.624^**	0.535	0.022	1.067	0.728

Eint			-	**2.739***	0.230	0.869	**1.799^**	1.547
Emic				-	**2.600***	**2.173^**	0.436	0.882
Esid					-	0.723	**1.645^**	1.308
Epil						-	1.290	0.885
Epro							-	0.488
Eres								-

Table 2: Values of the Z Statistic derived from Mann-Whitney U - Wilcoxon Rank Sum W Tests of strike rates for six species of eucalypt on Neranleigh-Fernvale Group derived substrates in the Study area (***** indicates significant difference @ 1 % Confidence Limit; **^** indicates significant difference only @ 5 % CL).

Mann Whitney U - Wilcoxon Rank-sum Tests established that there was no significant difference between the strike rate for Forest Oak *Allocasuarina torulosa* vs Brush Box *Lophostemon confertus* (0.08 vs 0.06 : z= .283). The remaining species beneath which Koala faecal pellets were found on the Neranleigh-Fernvale Group geomorphological unit are represented by inadequate enumerative datasets which otherwise fail to meet the established standards for analyses.

No strike rates otherwise indicative of a significant deviation from mean strike rates on a plot by plot basis were established by Chi-Square analyses.

Spearman's Rank Correlation Procedure indicated that there was no significant relationship between the density of *E.microcorys* and its level of use by Koalas.

b) Quaternary Alluvials and Sands

A total of 17 primary plot sites and 8 supplementary quadrats were sampled on the Quaternary Alluvial and Sand geomorphological unit. A total of 1,332 trees were assessed including 11 species of eucalypt (419 individual trees) and 17 species of non-eucalypt (913 individual trees). Nineteen of the 25 sites sampled contained evidence of utilisation by Koalas, with faecal pellets recorded from beneath 6 species of eucalypt and 12 species of non-eucalypt (Tables 3 and 4 of Appendix).

The total number of trees with one or more Koala faecal pellets recorded beneath them collectively comprised 61 of the 419 eucalypts and 69 of the 913 non-eucalypts assessed. The number of Koala faecal pellets recorded beneath eucalypts ranged between 1 and 72 (Mean = 3.579, Median = 1.0, Standard Deviation = 7.947, n = 216) while the number of Koala faecal pellets recorded beneath non-eucalypts ranged between 1 and 46 (Mean = 3.473, Median = 1.0, Standard Deviation = 6.992, n = 93). There was a significant difference between the average number of Koala faecal pellets found beneath eucalypts and those found beneath non-eucalypts. The highest faecal pellet count was recorded beneath an *Eucalyptus tereticornis* at Site T008 (n= 72).

Data sets suitable for statistical analyses were obtained for 3 of the 6 eucalypt species (Pink Bloodwood *Eucalyptus intermedia*; Swamp Mahogany *E. robusta* and Forest Red Gum *E. tereticornis*) and for 5 of the 12 non-eucalypt species (Cypress Pine *Callitris columellaris,* Swamp Oak *Casuarina glauca,* Brush Box *Lophostemon confertus,* Swamp Box *Lophostemon suaveolens* and Broad-leaved Paperbark *Melaleuca quinquinervia*) beneath which Koala faecal pellets were recorded (Table 5).

Activity levels at the 19 "active" sites sampled on the Quaternary Alluvial and Sand geomorphological unit ranged from 2.4 % to 45.4 % (Mean = 16.3 %, Standard Deviation = 14.3 %, n= 18). The highest activity level of 45.4 % was recorded for site T054 which comprised *Eucalyptus robusta, E.signata, E.propinqua, E.intermedia, Melaleuca quinquinervia and Callitris columellaris*.

Krusskal-Wallis 1-way Anova's established that there were significant differences in the summed proportional strike rates on a species by species basis for eucalypt species (Chi-Square = 7.7767, 2df, p= .0205) but not for non-eucalypt species (Chi-Square = 1.7182, 4df, p = .7874).

While *E. tereticornis* had the highest mean strike rate, Mann Whitney U - Wilcoxon Rank-sum Tests established that there was no significant difference between the strike rate for this species and that of *E. robusta* (0.71 vs 0.61 : z= .273). A significant difference was recorded between both the strike rate of *E. tereticornis* vs *E. intermedia* (0.71 vs 0.18 : z= 2.392) and *E. robusta* vs *E. intermedia* (0.61 vs 0.18 : z= 2.404).

Spearman's Rank Correlation Procedure indicated that there was no significant relationship between the densities of either *E.robusta* or *E.tereticornis* and their level of use by Koalas.

Mann Whitney U - Wilcoxon Rank-sum Tests confirmed that there was no significant difference between the strike rates for any of the non-eucalypt species recorded with adequate data sets on the Quaternary Alluvial and Sand geomorphological unit (Table 3).

The remaining eucalypt and non-eucalypt species beneath which Koala faecal pellets were found on this geomorphological unit are represented by inadequate enumerative datasets which otherwise fail to meet the established standards for adequate analyses.

	Ccol	***Cgla***	***Lcon***	***Lsua***	***Mqui***
Ccol	-	0.763	0.780	1.040	1.121
Cgla		-	0.121	0.479	0.463
Lcon			-	0.282	0.418
Lsua				-	0.412
Mqui					-

Table 3: Values of the Z Statistic derived from Mann-Whitney U - Wilcoxon Rank Sum W Tests of strike rates for five species of non-eucalypt on Quaternary Alluvial and Sand derived substrates in the Study area (***** indicates significant difference @ 1 % Confidence Limit; **^** indicates significant difference only @ 5 % CL).

3.2 Comparison of Sites on Neranleigh-Fernvale Group to Quaternary Alluvial and Sand Geomorphological Units

On both the Neranleigh-Fernvale Group geomorphological units (Pzn) and the Quaternary Alluvial and Sand geomorphological units (Qa) there were significant differences in the activity levels recorded from sites containing one or more of the preferentially utilised tree species (puts) when compared to those without the preferentially utilised tree species (**Pzn** - mean activity level for sites with puts = 14.1% + or - 2.2% *vs* sites without puts = 0.81% + or - 0.52%; **Qa** - mean activity level for sites with puts = 17.05% + or - 3.39 *vs* sites without puts = 0.57% + or - 0.57%).

NERANLEIGH-FERNVALE GROUP METAMORPHICS

Eucalypts

White Mahogany	***Eucalyptus acmenoides***	(*x*=0.06; n=175; **v**)
Narrow-leaved Ironbark	***E. crebra***	(p=0.31; n=13; nv)
Red Bloodwood	***E. gummifera***	(*x*=0.18; n=71; **v**)
Pink Bloodwood	***E. intermedia***	(*x*=0.08; n=178; **v**)
Tallowwood	***E. microcorys***	(*x*=0.33; n=151; **v**)
Grey Ironbark	***E. paniculata***	(*x*=0.04; n=62; **v**)
Blackbutt	***E. pilularis***	(*x*=0.10; n=229; **v**)
Grey Gum	***E. propinqua***	(*x*=0.29; n=88; **v**)
Red Mahogany	***E. resinifera***	(*x*=0.22; n=69; **v**)
Pink Bloodwood	***E. intermedia***	(*x*=0.08; n=178; **v**)
Northern Grey Ironbark	***E. siderophloia***	(*x*=0.12; n=67; **v**)
Silvertop Ash	***E. sieberi***	(p=0.20; n=5; nv)
Forest Red Gum	***E. tereticornis***	(*x*=0.23; n=10; nv)

Non-eucalypts

Brush Ironbark Wattle	***Acacia aulacocarpa***	(p=0.14; n=7; nv)
Forest Oak	***Allocasuarina torulosa***	(*x*=0.08; n=183; **v**)
Swamp Oak	***Casuarina glauca***	(p=0.04; n=24; nv)
Brush Box	***Lophostemon confertus***	(*x*=0.06; n=128; **v**)
Broad-leaved Paperbark	***Melaleuca quinquinervia***	(p=0.09; n=22; nv)

Table 4. Species of eucalypt and non-eucalypt sampled on substrates derived from Neranleigh-Fernvale Group geomorphological units in the study area, beneath which one or more Koala faecal pellets were recorded (p=proportional strike rate; *x*= arithmetic mean; n=number sampled; v=statistically valid; nv=statistically non-valid).

QUATERNARY ALLUVIALS AND SANDS

Eucalypts

Pink Bloodwood	***E. intermedia***	(*x*=0.18; n=60; **v**)
Tallowwood	***E. microcorys***	(p=0.28; n=7; nv)
Swamp Mahogany	***E. robusta***	(*x*=0.61; n=78; **v**)
Scribbly Gum	***E. signata***	(*x*=0.40; n=5; nv)
Forest Red Gum	***E. tereticornis***	(*x*=0.71; n=32; **v**)
Swamp Mahogany *X* FRG	***Hybrid Eucalypt***	(p=1.0; n=2; nv)

Non-eucalypts

Coast Banksia	***Banksia integrifolia***	(p=0.04; n=27; nv)
Cypress Pine	***Callitris columellaris***	(*x*=0.22; n=48; **v**)
Forest Oak	***Allocasuarina torulosa***	(*x*=0.08; n=183; **v**)
Swamp Oak	***Casuarina glauca***	(p=0.10; n=52; **v**)
Willow Bottlebrush	***Callistemon salignus***	(p=0.29; n=7; nv)
Blueberry Ash	***Elaeocarpus reticulatus***	(p=0.4; n=5; nv)
Brush Box	***Lophostemon confertus***	(p=0.06; n=82; **v**)
Swamp Box	***Lophostemon suaveolens***	(p=0.05; n=321; **v**)
Paperbark	***Melaleuca linariifolia***	(p=0.05; n=62; nv)
Broad-leaved Paperbark	***Melaleuca quinquinervia***	(p=0.09; n=22; nv)

Table 5. Species of eucalypt and non-eucalypt sampled on substrates derived from Quaternary Alluvial and Sand geomorphological units in the study area, beneath which one or more Koala faecal pellets were recorded (p=proportional strike rate; *x*= arithmetic mean; n=number sampled; v=statistically valid; nv=statistically non-valid).

3.3 Remaining Geomorphological Units

An additional geomorphological unit associated with localised occurrences of Lamington Volcanics occurs within the study area. However, these areas have been either cleared for agricultural or urban development or support predominantly remnant rainforest communities. Koala habitat assessments within these areas were limited by both the absence of any substantial areas of sclerophyll forest or woodland and the lack of evidence of Koala presence or activity.

3.4 Vegetation Communities

The following vegetation communities were identified by Landmark Ecological Services Pty Ltd (1996) for the Tweed coastal study area. The mapped distribution for each of these communities is presented in Figure 4.

Rainforest

Three broad types of rainforest were identified within the study area including littoral, subtropical and dry rainforest.

Littoral rainforest: occurred on coastal sand substrates behind foredunes. *Cupaniopsis anacardioides, Banksia integrifolia* and *Acronychia imperforata* were common to dominant in the upper stratum with *Acmena smithii, Cryptocarya triplinervis* and *Rhodomyrtus psidioides* common in the midstratum. Common ground species included *Austromyrtus dulcis, Doodia aspera* and *Lomandra longifolia.*

Subtropical rainforest: occurred in moist sheltered sites on fertile soils mainly on floodplain areas and gullies. Remnants were usually confined to riparian areas with *Elaeocarpus grandis, Archontophoenix cunninghamiana*, *Sloanea australis* and *Syzygium francisii* common in the upper stratum. *Castanospermum australe, Cyathea australis* and *Dysoxylum mollissimum* were often present in the midstratum. The ground stratum were usually sparse with a few seedlings present and where the canopy was disturbed exotic species such as *Lantana camara* and *Ageratina riparia* tended to dominate. *Alocasia brisbanensis* was often found on the edges.

In the most fertile and protected sites *Toona ciliata*, *Diploglottis australis* and *Gmelina leichhardtii* were often present in the upper stratum.

Dry rainforest: *Araucaria cunninghamii* very tall closed forest occurred where soils were drier, mainly on slopes and ridges. *Lophostemon confertus, Archontophoenix cunninghamiana, Eucalyptus grandis* and *Flindersia* spp. were common associates in the overstorey with *A. cunninghamii* sometimes forming dense stands with few other species present. Midstratum species commonly included *Mallotus philippensis, Archirhodomyrtus beckleri* and *Flindersia schottiana*. The ground stratum usually included species such as *Blechnum cartilagineum, Morinda jasminoides, Alpinia caerulea* and *Lomandra* spp.

Cinnamomum camphora Mid-high to Tall Closed Forest and Woodland

C. camphora-dominated forest and woodland occurred on high to medium fertility soils throughout Tweed Shire.

On moist soils, rainforest species including *Lophostemon confertus* and *Eucalyptus grandis* were occasional to common in the overstorey. On dry or low fertility soils eucalypt species such as *E. microcorys, E. siderophloia, E. propinqua, E. acmenoides, E. intermedia* and *E. pilularis* were often present. However, *C. camphora* was dominant on soils of high fertility. *C. camphora* and subtropical rainforest species were usually common in the understorey.

***Lophostemon confertus* +/- *Eucalyptus grandis, E. pilularis, E. siderophloia, E. acmenoides, E. intermedia, E. propinqua, E. microcorys* (+/- rainforest species) Midhigh to Very Tall Closed Forest to Woodland**

Lophostemon confertus forests occurred on well-drained medium to high fertility soils in sheltered, less fire-prone areas. On moist soils rainforest species were often present in the canopy and in these situations if the forest remains undisturbed rainforest will eventually replace the *L. confertus* forest. An ecotonal species, *L. confertus* graded into *Eucalyptus* dominated forest and was often common in the understorey of *E. pilularis* tall closed forest, an indication that fire had been excluded for some time.

On drier lower fertility soils where eucalypt species were common or co-dominant in the overstorey *Daviesia arborea*, *Hovea linearis, Guioa semiglauca* and *Eupomatia laurina* typically dominated the midstratum. Higher fertility dry sites supported dry rainforest species such as *Archirhodomyrtus beckleri*, *Acacia bakeri*, *Endiandra globosa*, *Cryptocarya laevigata, Rhodamnia maideniana* and *Drypetes australasica* in the midstratum. Higher fertility soils in moist sheltered sites on basalt supported subtropical rainforest species including *Acmena ingens, Syzygium francisii, S. luehmannii* and *Hicksbeachia pinnatifolia*.

Where the canopy was open and eucalypt species were present, *Themeda australis, Imperata cylindrica* and *Lomandra longifolia* were common in the ground stratum. In closed forest with rainforest species present *Ageratina riparia, Alpinia caerulea, Blechnum cartilagineum* and *Arachnioides aristata* were the dominant species.

Eucalyptus pilularis - E. siderophloia - E. acmenoides -E. intermedia -E. propinqua - E. microcorys- Lophostemon confertus - E. resinifera - E. saligna - Syncarpia glomulifera **Tall to Very Tall Closed Forest to Woodland (above 10 m asl)**

Eucalyptus pilularis was dominant to occasional on ridgetops and upper slopes on metasediments but was generally absent on the more sheltered lower slopes where moisture levels were higher and the vegetation was less fire-prone. In this association *Lophostemon confertus* was dominant to occasional in the mid to lower understorey where fire had been absent for some time.

On the lower slopes where the metasediments met the coastal sandplain associations often contained *E. robusta* and *E. signata* and on lower slopes where the metasediments met alluvial soils *E. propinqua* and *E. tereticornis* were frequently present.

The mid-stratum of this association was dominated by *Allocasuarina torulosa* and *Mallotus philippinensis* in drier sites grading into *Cryptocarya rigida, Eupomatia laurina* and *Synoum glandulosum* in wetter sites. Where *L. confertus* was common in the upper stratum, rainforest species such as *Acacia bakeri*, *Ailanthus triphysa*, *Endiandra globosa, Endiandra discolor* and *Cryptocarya microneura* were commonly present in the mid-stratum.

The ground stratum varied from *Themeda australis, Pteridium esculentum* and *Imperata cylindrica* in open forest to *Hypolepis glandulifera, Lomandra longifolia* and *Doodia caudata* in closed forest.

Melaleuca quinquinervia - Lophostemon suaveolens - Eucalyptus robusta - E. signata - Casuarina glauca - Melicope elleryana - Archontophoenix cunninghamiana - Glochidion sumatranum Mid-high to Very Tall Closed Forest to Woodland

Melaleuca quinquinervia occurred in low-lying, regularly inundated areas grading into *Casuarina glauca* as salinity increased. With less regular inundation, *E. robusta* became dominant, grading into *E. signata* on low dunal ridges. On waterlogged soils in protected areas *A. cunninghamiana, Glochidion sumatranum* and *Melicope elleryana* often formed an association.

Banksia spp. - _Allocasuarina littoralis - Casuarina equisetifolia - Acacia sophorae_ Woodland and Shrubland

This community occurred on the coastal dunes, often where sand-mining had taken place on areas once covered in littoral rainforest.

Callitris columellaris Mid-high to Tall Woodland to Closed Forest

Pockets of *Callitris columellaris* were found on old dunal sands. A larger area to the south of the Wooyung Road occurred with *Acacia aulacocarpa* and *Monotoca elliptica* common to co-dominant in the overstorey. Other occurrences of *C. columellaris* tended to be localised with few other species present.

Distribution of the Vegetation Communities

Mixed eucalypt forests in which *Eucalyptus pilularis*, *E. siderophloia, E. microcorys, E. propinqua, E. intermedia, E. acmenoides* and *E. resinifera* were the most common species (Community 4) occurred on the slopes and ridges. *Eucalyptus pilularis*-dominated dry open forest predominated on the ridges and upper slopes. *Eucalyptus propinqua* was common in areas where soils were less siliceous and *E. acmenoides* and/or *E. resinifera* occurred in sheltered areas. Moist open forest, usually dominated by

Lophostemon confertus and with a mesophytic understorey, graded into the drier forests on the middle and lower slopes. *Lophostemon confertus* tended to be an ecotonal species and in fertile sites was being replaced by rainforest where fire was excluded. The most common eucalypts in moist open forest were *E. microcorys, E. intermedia, E. acmenoides, E. siderophloia, E. pilularis* and *E. propinqua*. *Eucalyptus grandis*, an indicator of past disturbance, also occurred on the lower slopes but was most common on sheltered alluvial soils, usually with a rainforest understorey and strongly associated with *L. confertus*. *Eucalyptus saligna* occurred mainly on soils of moderate fertility on the middle and lower slopes, usually in association with *L. confertus*, *E. microcorys* and/or *E. siderophloia* and was found only in the north-west of the mapping area on the ridge to the north of Dunbible Creek and in Mooball State Forest.

On the lower slopes where the metasediments met the sandplain, associations dominated by *Eucalyptus signata, E. robusta, E. intermedia* and *E. resinifera* graded in and where the metasediments met alluvial soils, *E. propinqua and E. tereticornis* were often present. *Melaleuca quinquinervia* woodland to very tall closed forest occurred in low, regularly inundated areas. Where salinity increased, *Casuarina glauca* graded in. On sand with increased elevation *Eucalyptus signata* tended to dominate. On drier soils, *Eucalyptus robusta*, then *E. signata* became dominant. *Archontophoenix cunninghamiana, Glochidion sumatranum* and *Melicope elleryana* often formed an alliance on waterlogged soils.

On moist soils *Lophostemon confertus* and *Eucalyptus grandis* and/or rainforest species were occasional to common in the overstorey. On dry or low fertility soils eucalypt species such as *E. microcorys, E. siderophloia, E. propinqua, E. acmenoides, E. intermedia* and *E. pilularis* were often present.

Littoral rainforest occurred on coastal sand substrates behind the foredunes with subtropical rainforest present in moist sheltered sites on fertile soils mainly on the floodplain areas and in gullies on the lower slopes of the ranges. Dry rainforest occurred where soils were drier, mainly on slopes and ridges.

Occurrence of Threatened Plants and other ROTAP Species

Tweed LGA is the stronghold for a high number of Threatened Plant and other Rare or Threatened Australian Plant (ROTAP) species and represents the southern limit of distribution for a number of species occurring primarily in south-east Queensland. Species encountered during ground-truthing comprised:

PLANT SPECIES	ROTAP Listing	Schedule 1 and 2, Threatened Species Conservation Act 1995
Cassia brewsteri var. *marksiana*	2RCi	-
Cupaniopsis newmannii	2RC-	-
Davidsonia pruriens var. *jerseyana*	2ECi	E
Davidsonia sp. nov	2ECi	E
Endiandra floydii	2VC-	E
Endiandra globosa	2RCa	-
Hicksbeachia pinnatifolia	3RC-	V
Macadamia tetraphylla	2VC-	V
Randia moorei	3ECi	E
Rhodamnia maideniana	2RC-	-
Syzygium moorei	2VCi	V

Particularly significant species included the Endangered *Davidsonia pruriens* var. *jerseyana*, which was found in a number of locations in the Burringbar Range, *Davidsonia* sp. nov and *Endiandra floydii*, which were located in a gully near Sleepy Hollow, and *Randia moorei* located in a riparian rainforest remnant at Cudgera Creek.

4.0 DISCUSSION

The results of this study support a model of habitat utilisation by Koalas that is principally based on only three species of eucalypt namely Swamp Mahogany *Eucalyptus robusta*, Tallowwood *Eucalyptus microcorys* and Forest Red Gum *Eucalyptus tereticornis,* particularly where the latter occurs on alluvial deposits of Quaternary origin. All three of these species are the subject of preferential utilisation by Koalas in the study area and there are no indications that their level of utilisation by Koalas is dependant upon their respective densities when growing in optimum habitat. Additionally, the importance of the naturally occurring *E.robusta x E. tereticornis* hybrid must also be recognised. The occurrence of this species is quite localised and it was not possible to develop an adequate data set for either analysis and/or modelling purposes. None the less, the inspection of individual trees undertaken during fieldwork, coupled with the results of other studies in the Tweed Coast (Phillips, in prep) clearly establish its importance as a food tree for Koalas at a level indicative of preferential utilisation.

The significance of Grey Gum *E. propinqua* also needs to be placed in context. In contrast to those species detailed above, *E. propinqua* is the only species which demonstrates a density dependant strike rate with preferential utilisation only occurring at low densities or upon isolated trees in higher density stands, a phenomena likely to be the result of influences by micro-edaphic variables such as the availability of free water and/or nutrients. The long term persistence of scratch marks on this species (a phenomena associated with the decorticating process) has historically elevated its perceived importance to Koalas and the results obtained for the Tweed Coast are consistent with other studies (Phillips & Callaghan, 1996; Phillips, in prep).

Notwithstanding issues associated with disease and the depredations of both motor vehicles and dogs on the Koala population, the presence of the preferentially selected tree species' must be recognised as major limiting factors affecting the distribution and abundance of Koalas in the study area.

The Koala habitat assessment work conducted in the Tweed Coast study area over a period in excess of twelve months, together with the results of research on the Searanch Koala Population (Phillips, in prep), clearly indicates that there is unlikely to be any seasonal shift in preferential utilisation of tree species by Koalas within the study area.

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

Primary Koala Habitat: recognisable floristic alliances and/or associations wherein tree species known to be both preferentially utilised by Koalas **and demonstrating a strike rate which is independent of density** are a dominant or co-dominant component of the overstorey vegetation.

Secondary Koala Habitat: ***Secondary (A) Habitat*** recognisable floristic alliances and/or associations wherein tree species known to be preferentially utilised by Koalas, on average, constitute less than 35% of the overstorey vegetation.

Marginal Koala Habitat: ***Secondary (B) Habitat*** recognisable floristic alliances and/or associations wherein tree species known to be preferentially utilised by Koalas are largely absent or otherwise occur at very low densities (<10%).

Habitat Value "Unknown": forest alliances and/or associations wherein the species composition remains unknown, but where it is considered possible for one or more preferentially utilised tree species to occur as a dominant or co-dominant component of the overstorey.

A categorical breakdown of Koala habitat in the Tweed Coast study area based on the results of fieldwork and subsequent modelling (Figure 5) has been determined as follows:

Habitat Category	**Area (Ha)**	**Percent of Study Area**
PRIMARY HABITAT	956.6	2.5 %
SECONDARY HABITAT (A)	4,043.2	10.7 %
SECONDARY HABITAT (B)	3,862.2	10.3 %
UNKNOWN HABITAT	252.8	0.7 %
OTHER VEGETATION	3,577.2	9.5 %
MAINLY CLEARED	24,916.1	66.3 %
TOTAL	**37,608.1**	**100 %**

Each of the three habitat categories can constitute critical habitat from the Koalas perspective (Core Habitat for the purposes of SEPP No. 44). However, each differs significantly in terms of its relevance to the long term management of Koalas. The Primary Habitat category contains high densities of the preferentially utilised species. In the absence of results which suggest a level of use which is density dependant, it follows that Primary Habitat areas will also have a correspondingly higher carrying capacity with resulting smaller home range areas required by the resident koalas. In contrast, areas of Secondary Habitat have a lower carrying capacity and support lower density populations, the individual koalas within them requiring larger home range areas in response to the lower densities of the preferentially selected species. Thus the effective conservation and management of both Primary and Secondary Habitat(Class A), which differ in their potential carrying capacity, are integral to the long term future of koalas in the study area.

Preferentially utilised tree species may occasionally occur in areas of Secondary (B) Habitat (*Marginal Habitat*) and/or on agricultural land. However, the carrying capacity of Marginal Habitat is lower again than any of the preceding categories. In the case of agricultural land supporting scattered individuals, the large distances between otherwise isolated food trees further predisposes animals to predation or death by misadventure. Marginal Habitat is subsequently considered unlikely to be capable of supporting breeding aggregations over the long term.

Thus the habitat categories recognised by the Atlas clearly focus on carrying capacity. While such distinctions are necessary from a long term management perspective, they do not lessen the importance of the preferentially utilised tree species wherever they occur in the study area.

The strong association between the presence of the preferentially utilised species and high koala activity levels supports a contention that the higher than expected strike rates on other tree species in these areas which are not otherwise the subject of preferential utilisation are primarily due to the presence of these particular species. It is also clear that significant levels of activity also extend into adjoining areas of otherwise secondary habitat. In this regard it is not so much the nutritional value of these tree species that is important, rather it is their proximity to those species subject to preferential utilisation and to this end they must be considered an important habitat component from the koalas perspective, providing secure roosting and interaction areas in addition to opportunistic browsing opportunities. The importance of these areas for modelling purposes has been accommodated by provision of a 100m "activity" buffer around all areas of Primary Habitat.

4.1 Tweed Coast Koala Habitat Atlas Modelling

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

Densities for preferentially utilised tree species were determined on the basis of data from field based Atlas and vegetation assessments together with descriptions for each of the identified floristic associations provided in conjunction with the vegetation mapping report for the study area prepared by Landmark Ecological Services Pty Ltd.

4.2 HABITAT DESCRIPTIONS

Primary Koala Habitat

(956.6 hectares; 2.5% of the study area)

1. Communities dominated by Swamp Mahogany *E. robusta* growing on Aeolian and Swamp soil landscapes associated with Quaternary Deposits of largely Pleistocene origin;

2. communities dominated by Swamp Mahogany *E. robusta* and/or Forest Red Gum *E. tereticornis* growing on Transferral landscapes associated with alluvial deposits;

3. communities dominated by Forest Red Gum *E.tereticornis* and/or the naturally occurring hybrid *E. robusta* x *E. tereticornis* growing on Alluvial soil landscapes associated with Quaternary and Neranleigh-Fernvale Group geomorphologies; and

4. communities dominated by Forest Red Gum *E. tereticornis* growing on erosional landscapes of predominantly yellow podzolics and lithosols associated with Neranleigh-Fernvale Group geomorphologies.

Secondary Koala Habitat (Class A)

(4,043.2 hectares; 10.7% of the study area)

5. Forest communities on Aeolian and/or Swamp and/or Transferral soil landscapes supporting specimens of *E. robusta* and/or *E. tereticornis* and/or the naturally occurring hybrid *E. robusta* x *E. tereticornis* as sub dominant components of the overstorey;

6. Forest communities on erosional soil landscapes associated with the Neranleigh-Fernvale Group geomorphologies which are supporting specimens of *E. tereticornis*, Tallowwood *E. microcorys* and/or Grey Gum *E. propinqua* as sub-dominant components of the overstorey. Both *E. microcorys* and *E. propinqua* are species which will sometimes occur at sufficient densities in some areas to warrant classification as Primary Habitat.

Secondary Koala Habitat (Class B)

(3,862.2 hectares; 10.3% of the study area)

Forest communities, including agricultural and/or largely cleared lands supporting low densities of the abovementioned species.

Unknown Koala Habitat

(252.8 hectares; 0.7% of the study area)

These areas include any forested vegetation remnants that could not be surveyed within the constraints of the vegetation mapping exercise and which are subsequently considered to be of potential although as yet unquantified significance as Koala habitat.

4.3 Distribution and Status of the Tweed Coast Koala Population

The habitat categories which are the focus of the main Koala populations and which have the greatest potential for the effective long term conservation and management of the Tweed Coast Koala population include Primary Habitat and Secondary (Class A) Habitat which collectively comprise 4,999.8 hectares or approximately 54.8 % of the remaining forest in the study area. Field research suggests that approximately 80% of the Primary Habitat category and a similar proportion of Secondary (Class A) Habitat is no longer supporting stable populations, the contention supported by the frequently low activity levels recorded during fieldwork, the proportion of inactive sites which otherwise contain species known to be preferentially utilised by Koalas and extensive foot based traverses of these areas.

The extent to which the Koala population has been influenced by historical land use practices and/or threatening processes appears significant and historical research may provide evidence to confirm a suspected 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 study area remains speculative, considered calculations on the basis of the total occupied areas of Primary Habitat and Secondary (Class A) Habitat as detailed above, in conjunction with density data of 0.4 animals/ha in Primary Habitat; 0.08-0.16animals/ha in Secondary Habitat (Phillips, in prep), produce an estimated Koala population of well below 500 and realistically between 200 and 300 individuals.

In order to view this 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 Koalas perspective suggest an "effective" population size for the entire study area of between 65 and 130 individuals (figures based on a 50:50 sex ratio at birth, a polygynous social structure with a strong female bias and 35% infertility). A relatively high degree of segregation and geographic isolation is also known to occur between Koala breeding aggregations within the study area. It is subsequently considered probable for a number of these sub-populations to already fall close to or below the minimum required for likely medium to long term survivorship (Bennett, 1990).

Given the degree of isolation from other known Koala populations and subsequent low probability of significant levels of recruitment from outside of the study area, together with hazards associated with further habitat disturbance or removal, predation by domestic and/or feral animals, bushfire and collision with motor vehicles, this Koala population should be considered highly vulnerable to endangered with poor prospects for long term survivorship.

4.4 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 Management Plans 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 areas of primary Koala habitat recognised for the purposes of the Tweed Coast Koala 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, the Swamp Mahogany *E. robusta* X Forest Red Gum *E. tereticornis* hybrid and Grey Gum *E. propinqua* was identified by the Koala Habitat Atlas as a preferentially utilised resource for Koalas but are not recognised by SEPP No. 44 for the purposes of identifying "potential koala habitat". Schedule 2 of SEPP No.44 further specifies Scribbly Gum *E. signata* as a Feed Tree Species. While this may be the case outside of the Tweed Coast Study area, its application for that purpose is not supported by the Atlas results which suggest a level of opportunistic use otherwise associated with the presence of preferentially utilised species.

Notwithstanding the above, all areas of Primary and Secondary Koala Habitat as defined by the Koala Habitat Atlas are potentially "Core" habitat as defined by SEPP No. 44.

4.5 Limitations of the Atlas Model

Comparison of completed Atlas field sites with the vegetation map established an initial accuracy measure of approximately 77%, with 54 of the 70 point samples provided by study plots conforming to the vegetation communities delineated regardless of considerations associated with potential GPS inaccuracies, photogrammetry corrections and other mapping errors. Subsequent ground truthing and refinement of the vegetation map suggest that at least 80-85% accuracy has been achieved.

5.0 RECOMMENDATIONS

The following recommendations are considered the **minimum** necessary to provide for the long term viability of Koala populations in the Tweed Coast study area.

1. 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/or Secondary habitat known to be occupied and/or utilised by breeding aggregations of Koalas, as evidenced by records of breeding females and/or by localised or widespread activity levels of 30% or greater as determined in accordance with the procedures detailed by Phillips & Callaghan (1995).

2. Initiate a moratorium on any further land clearing activities or development proposals which will contribute to the further fragmentation and/or degradation of remaining areas of Primary and Secondary habitat (Class A) which otherwise have the potential to support Koala breeding aggregations.

3. Amend Tweed Council's Environmental Planning documents to reflect the location and importance of identified Primary and Secondary (Class A) Koala habitat categories.

4. Institute a Tree Preservation Order over the following Eucalypt species in that area covered by the Tweed Coast Koala Habitat Atlas:

Tallowwood	*Eucalyptus microcorys*
Swamp Mahogany	*E. robusta*
Forest Red Gum	*E. tereticornis*
Hybrid	*E. tereticornis X E. robusta*
Small-fruited Grey Gum	*E. propinqua*

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

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

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 habitat on a minimum 5 year cycle.

6. 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 a measure of ecological integrity and increasing the carrying capacity for Koalas generally.

7. Seek to establish Conservation Agreements with respect to areas of Primary and Secondary Koala habitat (Class A) outside of Crown Estate.

8. Develop urban Koala management strategies for endangered populations in areas including South Tweed Heads, Piggabeen, Cabarita/Bogangar and Pottsville along with fringing suburban 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 dog attrition, vehicle calming, habitat management and restoration, and community awareness as detailed in the preceding Koala Habitat Atlas report.

9. In conjunction with recommendation number 1, proceed with upgrading the existing Piggabeen Road alignment rather than construction of the proposed Piggabeen Road Deviation.

10. Seek support, in consultation with the National Parks and Wildlife Service and the Australian Koala Foundation to re-establish viable Koala populations in suitable areas of formally occupied Koala habitat in the study area with a longer term view to re-establishing populations in suitable areas of habitat and thereby minimising the consequences of otherwise catastrophic stochastic impacts such as fire which may accelerate the extinction threat to remaining localised populations.

Protocols for the proposed translocation of Koalas will be drafted by the Australian Koala Foundation for the consideration of the National Parks and

Wildlife Service, the Koala Rescue Unit (Tweed Wildlife Carers) and Tweed Shire Council.

11. Design and implement, in conjunction with land holders and the National Parks and Wildlife Service, an effective and co-ordinated control program for feral dogs and foxes within areas of Primary and Secondary Koala habitat as detailed in recommendations 1 and 2 above.

12. Actively encourage community based reporting of Koala sightings, particularly those relating to the presence of females with joeys, with a view to identifying and monitoring the locations of remaining breeding aggregations.

13. Consistent with the requirements of SEPP 44, compile and maintain a central register of community based records of past and current Koala distribution in the study area.

14. 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 and Secondary Habitat (Class A) as designated by the Koala Habitat Atlas:

Primary Habitat : No further development should be approved within remaining areas of Primary Habitat where there is likely to be any negative impact upon that habitat, the latter measurable in terms of proposals which would otherwise result in any gross loss or damage to existing vegetation communities.

Exceptions to this rule should only apply to those specific remnants of Primary habitat contained within the study area as detailed in the preceding report.

Secondary Habitat : **New Urban Developments (as a condition of**
(Class A) **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 trees known to be preferentially utilised by Koalas;

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

c) ensure that subdivision designs are accompanied by corresponding Landscape Plans that ensure a minimum planting of at least one preferentially utilised tree species for every two residential allotments created;

e) ensure that trees identified for retention or planting are protected by site specific Tree Preservation Orders (where 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) Impose a **minimum** lot size of 1,500 square metres in order to maximise retention of native, with the further imposition of building envelopes and clusters to take advantage of already cleared areas ;

g) Enforce strict controls over domestic dog ownership, particularly with respect to roaming domestic dogs but **preferably**, prohibit the keeping of domestic dogs altogether;

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

i) 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.

Existing Urban Developments

a) Identify and delineate areas of significant Koala Habitat including individual trees or clusters of trees known to be important to Koalas in the area;

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 restricted vehicle speeds to a maximum of 40 km/hr at all times in areas with a known high 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 include significant Koala habitat, possibly where Koala populations have undergone localised extinction. Consequently, these areas may contribute to habitat available for future recolonisation or re-introduction of Koalas and **should not be dismissed** as being insignificant as Koala habitat unless future research establishes this to be the case.

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APPENDICES