The Tree Species Preferences of Koalas (*Phascolarctos cinereus*) inhabiting forest and woodland communities on Quaternary deposits in the Port Stephens area, New South Wales.

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Abstract

An assessment of the tree species preferences of koalas inhabiting forest and woodland communities on Quaternary deposits in the Port Stephens area of New South Wales was undertaken between November, 1994 and March, 1996. Using a combination of randomly generated plots and radial based assessments, a total of 3,847 trees were sampled, comprising 16 species of *Eucalyptus* and 16 species of non-eucalypt. Evidence of tree use by koalas, specifically the presence of koala faecal pellets, was recorded from beneath 11 species of *Eucalyptus* and 8 species of non-eucalypt. While faecal pellets were more commonly associated with *Eucalyptus spp*, there was no significant difference between the average number of faecal pellets recorded beneath eucalypts and non-eucalypts.

Tree species preferences were determined by analysis of log likelihood ratios derived from data based on the presence/absence of koala faecal pellets, rather than pellet counts. This approach established that there was significant variation in the levels of utilisation amongst and between the different tree species and that two species in particular, Swamp Mahogany *E. robusta* and Drooping Red Gum *E. parramattensis*, were most preferred by koalas in the study area. Further, utilisation of both *E. robusta* and *E. parramattensis* by koalas was commensurate with increases in the density of both species, indicating that the relative abundance of both was likely to be a significant consideration in terms of the carrying capacity of vegetation communities utilised by koalas. Increases in the levels of use of other tree species could also be positively associated with the presence of *E. robusta* and/or *E. parramattensis*. The results of the study have established the success with which an enumerative approach to the interpretation of faecal pellet data can be utilised to clarify the tree species preferences of koalas. Application of the approach for habitat assessment and modelling purposes is also discussed.

Introduction

The Koala *Phascolarctos cinereus* is an obligate folivore which feeds primarily on the genus *Eucalyptus* (Martin & Lee, 1984). Throughout their remaining range in eastern Australia, koalas have been reported as utilising a wide variety of eucalypt and non-eucalypt species, the specific details of which have been discussed by various authors (Hindell *et al* 1985; Lee & Martin, 1988; Hindell & Lee, 1991; Phillips, 1990). While such accounts tend to portray koalas as rather opportunistic in terms of their tree species preferences, it has been generally acknowledged that within a particular area, only a few of the available species of *Eucalyptus* will be preferentially utilised while others, including some non-eucalypt genera, appear to be utilised opportunistically for feeding or other behavioural purposes (Lee & Martin, 1988; Lee & Carrick, 1989; Phillips, 1990; Pahl & Hume, 1991; Hindell & Lee, 1991).

A recurring theme in the literature which deals with the management of free ranging koala populations (e.g. Lunney *et al*, 1990; Gordon, 1996) is a perception that habitat destruction represents the greatest threat to long term conservation of the species. From this perspective it is clear that habitat must be conserved. Unfortunately, there is little agreement among researchers as to which tree species are the most preferred by koalas (Phillips, 1990). As a consequence, recurring debate over exactly what constitutes koala habitat and which are the most preferred tree species in a given area tends to both overshadow and undermine the more pressing need to effectively conserve it, an issue which is exacerbated by the absence of a scientifically credible approach to habitat assessments in the first instance.

The Port Stephens area was identified as one of the richest Koala sites in New South Wales by a 1986-87 survey (Reed *et al*, 1991). Effective long term management of this significant koala population will be contingent upon a detailed understanding of its habitat requirements. The purpose of this study was to examine habitat utilisation by koalas in that part of the Port Stephens Local Government Area (LGA) which was known to support the bulk of the LGA's koala population (Callaghan *et al*, 1994). The study was undertaken with a view to identifying those tree species of most importance to koalas in the area. In doing so, the study also aimed to initiate an approach which had broader ramifications for koala conservation by not only contributing further to an understanding of the patterns associated with habitat use, but also by providing a tool with which the resolution of differences regarding tree preferences and the assessment of koala habitat could be achieved.

Methods

The Study Area

The Port Stephens LGA covers an area of approximately 97,000 ha and is located some 200 kilometres north of Sydney on the mid north coast of New South Wales (Figure 1). A significant proportion of the LGA is comprised of Quaternary deposits known as the Tomago Coastal Plain, an area of 35,760 hectares largely comprised of sandbeds of Pleistocene and Holocene origin, separated by a low lying inter-barrier of estuarine flats (Matthei, 1995; Murphy, 1995). To the north and west, alluvial Quaternary deposits derived from other geological strata also adjoin the sandbeds but were excluded from this study due to their differing origins and more complex soil structure[1].

The floristic composition and distribution of the various native vegetation communities which occur on the Tomago Coastal Plain have been described and mapped by Envirosciences (1992). Their report and associated maps identified a number of distinct vegetation types in the study area, from forest and woodland communities variously dominated by Smooth-barked Apple *Angophora costata*, Swamp Oak *Casuarina glauca*, Broad-leafed Paperbark *Melaleuca quinquinervia*, Blackbutt *Eucalyptus pilularis*, Scribbly Gum *E. signata*, Red Bloodwood *E. gummifera*, Swamp Mahogany *E. robusta* and Drooping Red Gum *E. parramattensis*, to wetlands and coastal heaths dominated by *Melaleuca spp*, *Leptospermum spp* and *Banksia spp*.

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Figure 1: Map showing regional location of Port Stephens LGA.

Selection of field sites

The study area was overlain with 1:25,000 scale vegetation maps which had been prepared by Envirosciences (1992) for the purposes of the Port Stephens Draft Koala Management Plan (Callaghan *et al*, 1994). Within the boundaries of the designated vegetation communities, field site localities were determined using a $50m^2$ grid based numerical overlay in combination with independently generated random numbers. The resulting site co-ordinates for the centre of each grid cell so selected were then transferred to Magellan "Trailblazer" GPS units to assist their location in the field. Site selection was driven by the need to sample the range of floristic variation within each of the vegetation communities to the fullest extent possible and to ensure that statistically useful data sets were compiled for each tree species. A minimum of four "replicates" were initially generated for each of the recognised vegetation communities; further sites were generated as required. To establish a measure of independence for each replicate,

[1] Quaternary landscape data provided in the related work by Lunney *et al* (in press) does include the results from sites which were located on these alluvial substrates.

field sites were dispersed as widely as possible over the distribution of each vegetation community in the study area. Wherever possible, field sites were not generated in areas affected by major habitat disturbances such as recent bushfire, urban development and/or major roads.

Assessment of Field Sites

Once located in the field (+/- 50m), each primary field site was established by using a compass, measuring tape and flagging tape to designate the corners of a 40m X 40m plot based on bearings along each of the four cardinal compass points from a central reference point. Towards the latter part of the study, supplementary field sites in the form of smaller radial plots (Phillips and Callaghan, 1995) were also employed to gather additional data.

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 study a "tree" was defined as: *"a live woody stem of any plant species (excepting palms, cycads, tree-ferns and grass-trees) which had a diameter at breast height (dbh) of 100 mm or greater"*.

Within each plot, the diameter at breast height of each tree was systematically measured and an area on the ground prescribed by a circle of radius of 100cm from any one point around the base of each tree carefully inspected for the presence of koala faecal pellets. All koala faecal pellets within the radial search area were counted and the total recorded. The faecal pellet count was initiated with a precursory inspection of the area described above, followed by a more thorough inspection of the substrate which included disturbance of the leaf litter and any ground cover. Where the distribution of faecal pellets fell within overlapping search areas brought about by two or more trees growing in close proximity to each other, the number of pellets within the area of overlap were allocated to each tree accordingly. 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.

Data Analysis

"Active" and "Non-Active" Sites

In order to describe the extent of tree use which could be attributed to each replicate, "activity levels" for each plot were expressed as the 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) sampled in the plot. Variation in plot based activity levels was assumed to be normally distributed.

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*, completed field plots were categorised as either "active" or "non-active" on the basis of whether koala faecal pellets were present or absent respectively. Only "active" plots were considered for analysis purposes in the first instance, whereas data relating to all "inactive" sites was reviewed in the light of results obtained by the approach detailed below.

Faecal Pellet Counts

In addition to the determination of median and modal faecal pellet scores, the average number of faecal pellets observed within the prescribed search area beneath each tree was calculated from all trees beneath which faecal pellets had been recorded. Similarly, the average number of faecal pellets recorded within the prescribed search area was also determined for trees in both "eucalypt" and "non-eucalypt" categories. Variances associated with the average score in each category were tested for homogeneity and the appropriate t-test used for comparison purposes.

Tree Preferences and Habitat Utilisation

Based on the approach proposed by Phillips *et al* (in prep), no further consideration was given to the total number of faecal pellets recorded beneath each tree, rather they were considered to be either present or absent, thus transforming the association between tree species and faecal pellets into that measured by a binary response variable. For a given tree species "*i*" the results from each active plot in the study area were pooled in order to obtain a proportional indice (P_i) or "strike rate". The strike rate was expressed as a percentage based on the number of individual trees of species "*i*" which had one or more Koala faecal pellets recorded beneath them (p_i), divided by the total number of trees (n_i) of that species sampled. Thus $P_i = (p_i/n_i) \times 100$.

Tree species preferences and other habitat utilisation considerations were determined by analysis of the pooled results from all "active" plots. Data sets for each of the tree species were regarded as most appropriate for analysis purposes when:

a) the data set had been obtained from at least 4 independent "active" sites; and

b) n_iP_i (the total number of trees of species "*i*" multiplied by the "strike rate" for that species) and $n_i(1-P_i)$ were both at least as large as 5.

All data which satisfied the above criteria were considered as part of a primary data set containing 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. Log likelihood ratios were used to examine the extent of variation amongst strike rates for each of the tree species in the primary data set. Significant heterogeneity was addressed by a re-arrangement of data sets for each species in order of decreasing strike rate and the resulting hierarchical model was then tested for homogeneity using simultaneous test procedures. Logarithmic regression was used to investigate the relationship between plot based strike rates and density (no. of live stems/0.16ha) for each tree species isolated by the above procedure as being most preferred; the density figures for each species being obtained directly from the study plots.

The extent of variation in the strike rates amongst each of the tree species which failed to satisfy the minimum criteria for inclusion in the primary data set was examined using a Kruskal-Wallis ANOVA. Where significant heterogeneity was indicated, between species comparisons were undertaken using the U statistic derived from a Wilcoxon two sample test.

A *post hoc* test of association (G-test of independence) was subsequently employed to test the relationship between the plot based strike rates for other tree species and the presence/absence of those species determined by the above procedures to be most preferred by koalas in the study area; the phi coefficient (ϕ) was calculated to determine the strength of any association.

Statistical procedures utilised for the study followed those detailed by Sokal & Rohlf (1995); SPSS 6.1 software was used for some components of the data analyses.

RESULTS

Data were collected from 45 primary and 11 supplementary plot sites (Figure 2). A total of 3,847 trees were assessed, collectively comprising 16 species of *Eucalyptus* and 16 species of non-eucalypt. Thirty three of the primary plots contained evidence of utilisation by Koalas, with faecal pellets recorded from beneath 11 *Eucalyptus spp* and 8 species of non-eucalypt (Table 1).

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Figure 2. Location of plot sites used to determine the tree species preferences of koalas inhabiting Quaternary Deposits in the Port Stephens LGA. The extent of the study area is indicated.

Species	No. sites	n_i	P_i (%)	Species	No. sites	n_i	P_i (%)
Eucalypts				**Non-eucalypts**			
E. robusta	14	348	55.5	*M.quinquinervia*	12	718	29.7
E. parramattensis	9	494	53.6	*A. costata*	22	263	24.7
E. piperita	7	171	42.1	*M. stypheloides*	5	33	24.2
E. pilularis	8	90	35.6	*B. serrata*	12	101	13.9
E. gummifera	16	224	30.8	*M. nodosa*	10	175	13.1
E. signata	13	351	29.3				
E. eugeniodes	3	26	15.4	*A. glauca*	2	8	25.0
E. globoidea	3	7	28.6	*M. linearfolia*	1	3	60.0
E. spp	3	6	16.7	*A. torulosa*	1	36	22.2
E. resinifera	2	10	10.0				
*E. botyroides**	1	4	100.0				
Others (3spp)	3	6		Others (8 spp)	8	33	
Total Trees		**1737**				**1370**	

Table 1. Collective results from all active sites (including supplementary plots) on Quaternary deposits in the Port Stephens LGA (* = species not native to the area).

The total number of trees with Koala faecal pellets recorded from within the prescribed search area beneath each tree comprised 977 of the 3107 trees present in the active sites. Activity levels of the 33 "active" plots ranged from 2.9% to 90.3% (x = 33.89%), the highest activity level being recorded from an *E. robusta* dominated community on the Tilligerry Peninsula. Faecal pellet counts beneath individual trees (all species) ranged from 1 to 388 (x = 8.34, median = 3, mode = 1, n = 977); the highest count recorded beneath a *Eucalyptus parramattensis*. The number of faecal pellets recorded within the prescribed search area beneath individual eucalypts ranged from 1 to 388 (x = 8.89, median = 3, mode = 1, n = 666) while the number of pellets recorded beneath non-eucalypts ranged from 1 to 204 (x = 7.15, median = 2, mode = 1, n = 311). While faecal pellets tended to be more commonly associated with eucalypts, there was no significant difference between the mean number of faecal pellets found beneath eucalypts and those found beneath non-eucalypts (t = -1.19, P > $.05_{[975]}$).

Tree Preferences

Data sets which met the specified criteria for inclusion in the primary data set were obtained for 6 of the 11 *Eucalyptus spp* and for 5 of the non-eucalypt species. Of the eucalypts, the range of strike rates varied from 55.5% for *Eucalyptus robusta* to 29.3% for *Eucalyptus signata*. There was significant heterogeneity amongst the strike rates when tested for Goodness of Fit ($G = 51.795 > \chi^2_{.001[4]}$). The results of an unplanned test for homogeneity (all replicates) using simultaneous test procedures subsequently established the presence of two homogenous data sets within the sample (Table 2). Both *E. robusta* and *E. parramattensis* were isolated by this process as the most preferred tree species.

Tree spp	*Erob*	*Epar*	*Epip*	*Epil*	*Egum*	*Esig*
P_i	.555	.536	.421	.356	.308	.293
HDS1	**X**	**X**	**X**			
HDS2			**X**	**X**	**X**	**X**

Table 2: Extent of homogeneity amongst the strike rates for the six species of *Eucalyptus* most frequently utilised by koalas on Quaternary deposits in the Port Stephens LGA. The descriptor "HDS" refers to each of the homogeneous data sets established using simultaneous test procedures.

There was no significant difference between the strike rates of *E. robusta* and *E. parramattensis* ($G = 0.19588 < \chi_{2\ .05[1]}$), nor was there any evidence to suggest that the levels of utilisation of either species varied in response to changes in their respective densities (*E. robusta*: rsq=0.006, F=$0.07_{[12]}$, sigF=0.799; *E. parramattensis*: rsq=0.003, F=$0.02_{[6]}$, sigF=0.905).

Strike rates of the three other *Eucalyptus spp* (*E. resinifera*, *E. globoidea* & *E. spp*) which were represented by data sets which did not satisfy the minimum standard adopted for the study were also examined. The extent of variation amongst the strike rates for these three species was not significant (Kruskal-Wallis ANOVA: $H = 0.473 < \chi^2_{.05[2]}$), nor were their respective strike rates (P_i = 18.2%, 20.0% & 16.7%) indicative of potentially significant levels of utilisation. Data relating to the two remaining *Eucalyptus spp* (*E. resinifera* & *E. botyroides*) beneath which faecal pellets were recorded were not considered suitable for analysis purposes.

Of the non-eucalypts, the range of strike rates varied from 29.7% for *Melaleuca quinquinervia* to 13.1% for *Melaleuca nodosa* (Table 1). There was significant heterogeneity amongst the strike rates when tested for Goodness of Fit ($G = 23.653 > \chi^2_{.001[3]}$). An unplanned test for homogeneity (all replicates) using simultaneous test procedures established that the relatively high levels of utilisation recorded for *M. quinquinervia* and *A. costata* were the primary cause of heterogeneity (Table 3).

Tree spp	*Mqui*	*Acos*	*Msty*	*Bser*	*Mnod*
P_i	.297	.247	.242	.139	.131
HDS1	**X**	**X**	**X**		
HDS2			**X**	**X**	**X**

Table 3: Extent of homogeneity amongst the strike rates for the five species of non-eucalypt most frequently utilised by koalas on Quaternary deposits in the Port Stephens LGA. The descriptor "HDS" refers to each of the homogeneous data sets established using simultaneous test procedures.

The results of the *post hoc* test of association established that the presence of *E. robusta* and/or *E. parramattensis* could be positively linked to the higher strike rates recorded for other tree species in the study plots ($G = 218.621 > \chi^2_{.001[1]}$). The level of this association was moderately strong ($\phi = 0.285$).

Inactive sites

Twelve primary and two supplementary field sites were deemed "inactive" due to the absence of koala faecal pellets. From these sites a total of 740 individual trees were sampled, comprising 14 species of *Eucalyptus* and 6 species of non-eucalypt. *E. pilularis* and *Angophora costata* were the tree species most commonly associated with inactive sites (Table 4).

Species	**No. sites**	**n**	**Species**	**No. sites**	**n**
Eucalypts			**Non-eucalypts**		
E. pilularis	8	105	*Angophora. costata*	11	132
E. gummifera	4	45	*Banksia serrata*	6	70
E. grandis	2	38	*Leptospermum sp*	2	4
E. resinifera	2	34	*Acacia sp*	1	5
E. umbra	2	29	*Allocasuarina glauca*	1	88
E. piperita	2	27	*Melaleuca quinquinervia*	2	69
E. robusta	2	17			
E. microcorys	1	34			
E. tereticornis	1	11			

E. agglomerata	1	2	
E. capitellata	1	3	
E. parramattensis	1	14	
E.signata	1	5	
E. spp	1	8	
Total Trees		**372**	**368**

Table 4: Tree species sampled by "inactive" sites on Quaternary deposits in the Port Stephens LGA.

Discussion

The results of this study provide cogent support for a model of habitat use by koalas inhabiting forest and woodland communities on Quaternary deposits in the Port Stephens LGA that is primarily focused on the preferential utilisation of only 2 of the 16 *Eucalyptus spp* that occur in the study area. The first of these two species, Drooping Red Gum *E. parramattensis*, has been largely overlooked in studies associated with the tree species preferences of koalas, with only Hawkes (1978) having noted that the species was reportedly browsed by koalas. One reason for this apparent lack of prominence in the koala literature is that *E. parramattensis* has a relatively limited geographic range in eastern Australia, its distribution being largely restricted to localised areas of the central coast and tablelands of New South Wales (Hawkes, 1978; Brooker & Kleinig, 1990, Harden, 1991). Nonetheless, it is notable that the potential of *E. parramattensis* as a food resource for koalas has actually been known for some time, being a matter formally communicated to Ambrose Pratt by Noel Burnet in his critical review of Pratt's (1937) work on the koala (R. Booth, pers comm.).

In contrast to *E. parramattensis,* Swamp Mahogany *E. robusta* has frequently been reported as a food tree species for koalas (*e.g.* Hawkes, 1978; Wicks, 1978; Lee & Martin, 1988; Summerville, 1990, Pahl *et al*, 1990). *E. robusta* is distributed in a narrow band along the eastern coast of Australia from near Nowra on the south coast of New South Wales to south-eastern Queensland, favouring low, swampy sites and estuarine alluvial soils (Hawkes, 1978; Harden, 1991, Brooker & Kleinig, 1996). Congreve and Betts (1978) also regarded *E. robusta* as "promising feed" in their study of the preferences demonstrated by an introduced koala population at Yanchep in Western Australia. However, the status of *E. robusta* in terms of its importance as a "preferred" food tree for koalas has been unclear and/or largely anecdotal, nor has it ever been quantified until the present study. By example, Pahl *et al* (1990) listed *E. robusta* as a "primary" food source for koalas but did not specify the criteria upon which such a distinction was made. Conversely, Lee & Martin (1988) and citing the work of Bob Warnecke, only listed *E. robusta* as an "occasional" food tree. *E. robusta* did not figure prominently in the work of Reed *et al* (1991), nor was it mentioned by Phillips (1990) in his discussion of tree species preferences arising out of the National Koala Survey data.

Inconsistencies such as those detailed above highlight the confusion that exists concerning the importance of particular tree species to koalas. While there is broad agreement amongst researchers that only a few tree species will be favoured by koalas in any one area, most have persisted in maintaining a somewhat catholic approach when detailing the most preferred species. Citing the work of others, Hindell & Lee (1990) unequivocally stated that the preferred tree species for koalas in New South Wales were *E. camaldulensis* and *E. tereticornis*. Hawkes (1978) also considered *E. tereticornis* (along with *E. punctata*) as "staple browse" for koalas in coastal NSW. Alternatively, Phillips (1990) described Sydney Blue Gum *E. saligna* as "...most popular with New South Wales Koalas...".

Generalisations such as those detailed in the preceding paragraph serve only to highlight the urgent need for an understanding of the tree species preferences of koalas at a much finer scale than has hitherto been applied. Similar conclusions have been reached by other workers (Cork *et al*, 1990; Norton & Neave, 1996) in suggesting that management of localised koala populations required a more precise assessment of the quality and nature of the food resource than that which was currently available. Consistent with this latter view, and based on an assumption that a significant association between a given tree species and the presence of faecal pellets is a reliable indicator of feeding preferences, the results of this study clearly establish the status of *E. parramattensis* and *E. robusta* as primary food tree species for koalas on the Tomago Coastal Plain. Interestingly, the results obtained by field sampling over a much larger geographic area using an identical approach to that described herein have now confirmed that *E. robusta* & *E. parramattensis* will the subject of preferential utilisation wherever they occur in association with extant koala populations (AKF, unpublished data).

In comparison to the results obtained for *E. robusta* and *E. parramattensis*, the strike rates of the remaining *Eucalyptus spp* and those of other genera such as *Melaleuca* and *Angophora* are generally not supportive of significant levels of utilisation by koalas in the study area. Indeed, the similarities in strike rates between these other species suggest that, from a koala's perspective, there is likely to be little difference between them. Such a view is generally consistent with that of Lee & Martin (1988) who observed that even in cases where non-eucalypts were persistently fed upon, the foliage of the preferred eucalypt species (in this case Manna Gum *E. viminalis*) consistently made up the bulk of the diet.

The results have also established that the strike rate for both *E. robusta* and *E. parramattensis* remains independent of their respective densities, i.e. the level of utilisation by koalas is commensurate with increases in the density of the preferred tree species, suggesting that a greater number of animals are utilising the resource in response to its greater relative abundance. A similar association based on observations of free ranging koalas was made by Hindell & Lee (1987) who reported a positive correlation between koala densities and that of the preferred food tree *E. viminalis* in the Brisbane Ranges of Victoria. Mitchell (1990) has similarly noted that large home range sizes could be associated with areas where the preferred tree species were more sparsely distributed, despite the presence of a variety of other eucalypt species. Such observations are crucial in terms of determining the importance of a given vegetation community for koalas. Cork *et al* (1990) considered that the key to the mapping of koala habitat was consideration of tree communities rather than individual tree species. As the results of this and the above studies suggest however, individual tree species, where they can be shown to be the subject of significant levels of utilisation by koalas, are likely to be a critical consideration in terms of carrying capacity. Moreover, we would suggest that an understanding of which tree species are important and which are not clearly increases the likelihood of finding koalas or evidence thereof, while also permitting the relative worth of the vegetation communities being utilised by koalas to be ascertained with a greater degree of confidence than that currently being practised.

The significance of the proportional strike rates for both *E. robusta* and *E. parramattensis* as determined by this study are difficult to accurately establish at this stage. Clearly, the presence of faecal pellets within the prescribed search area beneath the greater proportion of *E. robusta* & *E. parramattensis* sampled (55.5% & 53.6% respectively) provides direct evidence that such trees had been utilised by koalas on at least one occasion. Based on a consideration of the low central tendency statistics derived from the faecal pellet counts, and the probability issues associated with maintenance of such a consistently high strike rate (Phillips *et al*, in prep), it is likely that an even greater measure of importance should be attributed to these two species than that which has been evidenced by the results. To this end we would propose that species such as *E. robusta* and *E. parramattensis* represent a finite and critical resource for koalas at the population level. As such, and notwithstanding issues associated with habitat destruction, fire and the depredations of motor vehicles and dogs on the Port Stephens koala population (Callaghan *et al*, 1994), *E. robusta* and *E. parramattensis* must be considered as major limiting factors affecting the distribution and abundance of koalas in the study area.

The strong positive influence of the two most preferred tree species on the strike rates of other tree species lends further support to the preceding argument by inferring that the extent of differences between *E. robusta* and *E. parramattensis* and those of other tree species are actually likely to be greater than that which can be demonstrated by the results. In this regard we suggest that it is not so much the nutritional value of these other tree species that results in the increased levels of use, but rather their proximity to the most preferred species. Regardless, vegetation communities in which this phenomenon occurs must be recognised as important habitat components from a koala management perspective, given that they are providing secure roosting and/or social interaction areas in addition to supplementary browsing opportunities.

An appreciation of the results obtained by this study also allows several other issues associated with the modelling of koala habitat to be pursued. While the distribution of *E.robusta* and *E.parramattensis* on the Tomago Coastal Plain tends to be mutually exclusive, both are essentially limited by micro-edaphic considerations including soil type, drainage patterns, topography and proximity to the water table (Hawkes, 1978; Harden, 1991; Brooker & Kleinig, 1996). Thus, by overlaying the soil landscape data of Matthei (1995) and Murphy (1995) with a detailed vegetation map of the Tomago Coastal Plain, it could be argued that Aeolian, Swamp and Estuarine soil landscapes of

Quaternary origin which are supporting vegetation communities which contain one or the other, or both, of the preferentially utilised species *E. robusta* and *E. parramattensis*, will constitute significant koala habitat in the Port Stephens LGA. Recent work by Lunney *et al* (in press) has confirmed the validity of such a notion, establishing a highly significant degree of overlap between a habitat "model" based on the above (Phillips *et al*, 1996), and the results of an independent community based survey which provided information on the localities where koalas were most frequently observed.

Cork *et al* (1990) contended that the use of various approaches which relied upon data based on where koalas are, without consideration of where they are not, seriously limited the predictive potential of habitat models so derived. From this perspective, inactive sites such as those recorded during the process of this study can provide an important indicator of the extent to which extant koala populations are utilising the resources available to them. The consistent lack of activity indicators such as faecal pellets in vegetation communities containing tree species which are not known to be preferred by koalas are arguably a further measure of their lesser importance. Alternatively, once it has been determined that a particular tree species on a given substrate <u>is</u> the subject of preferential utilisation, it follows that a complete absence of activity indicators will provide indirect but compelling evidence of localised extinction processes associated with historical and contemporary range contractions at the population level. By example, three tree species which figure prominently in the inactive sites associated with this study, *E. pilularis*, *E. gummifera* and *A. costata* collectively form a distinctive vegetation community within the study area. Given that none of these species can be shown to be the subject of preferential utilisation in their own right, it seems reasonable to conclude that vegetation communities comprised solely of these species will only be of marginal importance as koala habitat. Inactive sites which contain *E. robusta* and/or *E. parramattensis* on the other hand, could not be viewed in the same light. A similar interpretation could be argued with regard to the single inactive site containing Tallowwood *E. microcorys*, a species which, in common with *E. robusta* and *E. parramattensis*, can otherwise be shown to be the subject of preferential utilisation by koalas across all soil types (AKF, unpublished data).

The approach recommended by Cork *et al* (1990) was to model the distribution of tree species using logistic regression and data on presence/absence from survey sites chosen to sample the range of climatic and geological variables in an area and thus predict the expected distribution of koalas and their habitat over a much larger area. However, this approach is problematical in that it assumes a state of dynamic natural equilibrium relatively free of perturbations such as those brought about by logging, fire and grazing by cattle, each of which has a profound ability to alter the intrinsic structure of natural vegetation communities (Reed, 1991; Catling, 1991; Cork & Catling, 1996; Catling & Burt, 1997). Further, the extent to which habitat can be "modelled" by this process will be limited by the resolution and accuracy of the spatial data required to support such a model (see Neave & Norton, 1991), the variable history of disturbance at each survey site (Cork & Catling, 1996) and the generally poor knowledge about the specific habitat requirements of target species, including that of the koala (Norton & Lindenmayer, 1991). Within the singular constraint imposed by the need for accurate soil landscape data, we suggest that the extrapolation of field based results such as those detailed herein, combined with detailed vegetation maps which provide a contemporary assessment of the distribution and composition of native vegetation communities, offers a preferable and more meaningful alternative for habitat mapping and/or modelling purposes. Hierarchical habitat categories based purely on the densities and relative abundance of most preferred tree species would also seem an appropriate measure by which to plan for the effective conservation of extant koala populations, more so given the clear relationship between these attributes and the carrying capacity of the vegetation communities in which they grow.

We conclude by reiterating that the resolution of issues associated with the identification of significant food trees for koalas has long acted as an impediment to effective conservation and management of the species. However, we believe that the approach described in this paper offers some assistance towards the accurate identification, mapping and modelling of koala habitat over large forested areas in eastern Australia. The use of a binary response variable for the purposes of interpreting faecal pellet evidence also permits a rapid and relatively cost effective approach to the identification of critical habitat components such as preferred tree species. As evidenced by this study, such an approach allows the area specific tree species preferences of koalas, along with other issues associated with habitat utilisation by this species, to be determined with an appropriate amount of rigour and a high level of confidence.

Acknowledgements

This project was undertaken as a component of post graduate research by the senior author. Field work was assisted by representatives of the AKF (Debbie Tabart, Ann Sharp & Jo Knights), San Diego Zoological Society (Chris Hamlin, Lenna Doyle, Jennifer Sanders, Danny Simpson, Bob Jones, Georgeanne Irvine, Ron Garrison, Jeff Freeman and Beckie Usnick), San Francisco Zoo (Steve Castillo, Patti Arsenault), Busch Gardens-Tampa (Mike Wells, Jason Green), Columbus Zoo (Adelle Absi), Rio Grande Zoo (Tom Silva), San Antonio Zoo (Deanna DeBo), Zoo Duisburg (Achim Winkler), and Lisbon Zoo (Eric Ruivo). Additional field assistance was provided by Christiane Scheffler (Germany), Philip Wright, Illan (South Africa), Terry Ward (NATF), Trish Fleissig, Mark Fitzgerald, Steve Blainey, Tiffany Knott, Dionne Coburn, Graeme Lloyd, Lindi Berghammer, Ben Phillips and Roselyn Schacht. Thanks also to Sandra Ball and Garry Warnes (Port Stephens Council) for assistance with the purchase and supply of food during field trips. Dave "SICO" Mitchell created the maps from digital data layers maintained by the Australian Koala Foundation and Rosie Booth provided historical details regarding the use of E. parramattensis. The support of the Executive Director, National Board and staff of the Australian Koala Foundation is also most humbly acknowledged. The draft manuscript benefited from critical reviews by Professor Peter Baverstock and Lyndon Brooks at Southern Cross University in addition to numerous friends and colleagues.

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