Redland City Council

Biodiversity Research Projects

Redlands Urban Tree Project

Cleveland Pilot Study

1.0 Executive summary

The Redlands Urban Tree Project Cleveland Pilot Study was conducted as part of Griffith University's Industrial Affiliate Program (IAP) in 2008. The study was commissioned by Redland City Council's Environmental Management Unit with the aim to develop and test a methodology to assess the quantity and quality of koala habitat throughout the urban footprint.

The pilot study involved stratified random sampling using land use planning zones. The number of hectares per zone represented each zone's proportional contribution to the area of Cleveland. Although 102 hectares were selected, desktop analysis was undertaken for only 76 hectares and only 25 of these were ground truthed. Ground truth work aimed to confirm overall tree abundance, palm tree abundance, percentage contribution of local and Australian natives and exotic tree species and the average number of koala habitat and food trees, including primary, secondary and preferred feeding trees.

The study found that:

- Desktop tree abundance was a good indicator of ground truth tree abundance however there was no correlation between desktop or ground truth tree abundance and the abundance of koala habitat and food trees.
- The average number of trees per hectare was 56.6, however many of these trees are unsuitable koala habitat: 34% were palms and 39% were exotics.
- Only 16% of trees were locally native whilst another 30% were other Australian native species.
- Koala habitat trees contributed to 9% of all trees and the average number per hectare was only 5.04. More than half of these were not koala food trees.
- Only 4% of all trees were either primary or secondary food tree species.
- Most of the primary food trees were also preferred food trees however these made up only 2% of all trees and the average number per hectare was 1.12.
- Whilst half of all koala habitat trees occurred on private land many of these were not food trees and almost two thirds of all preferred feeding trees occurred in Council road reserves or open space areas.

These findings highlight that there is great deficiency of local natives, koala habitat and food and trees within the urban landscape. Planting more koala food trees, especially primary and preferred food trees, is all the more important as climate change will likely reduce the quality of existing food resources such that koalas will need to eat more to get the same level of nutrition. Furthermore few food resources exist on private property yet there is much opportunity for Council to increase the abundance of koala food resources in road reserves and open space areas. Finally it is of utmost importance that planting more koala trees will not be an economic burden but an investment in Redlands urban green infrastructure which will yield ecological, social and economic benefits for the future to come.

2.0 Background

Redland City forms part of the 'Koala Coast' which is home to one of South East Queensland (SEQ)'s most significant koala (*Phascolarctos cinereus)* populations. The *Nature Conservation Act 1992* classifies SEQ koalas as 'vulnerable' due to the threat of urban development. Between 1996 and 2006 the Koala Coast koala population suffered a 26% decline and 68% of this decline occurred within Redland City's urban footprint (EPA 2007). This decline is associated with threats such as habitat loss, fragmentation and increased risk of mortality from car strikes and dog attacks (Mc Alpine *et al.* 2006, EPA 2006 and 2007). Habitat loss includes the loss of individual trees and forest patches as well as the removal of unfenced areas of open space, grass and other vegetation. Anthropogenic barriers, such as roads and fences and the threats of cars and dogs, also inhibit the movement and migration of urban koalas. Koala road mortality has been associated with vehicle speed yet habitat destruction, koala density and traffic volume may also be influencing factors (Dique *et al.* 2003). Furthermore, habitat loss and the stresses of the urban landscape appear to make koalas more susceptible to diseases such as Chlamydia, a urinary tract infection which increases infertility and mortality (EPA 2007, Creagh 1992). Unless appropriate action is taken to reduce and minimise these threats localised extinctions of Redlands koalas are highly likely (EPA 2007).

Although the *Queensland Nature Conservation (Koala) Conservation Plan and Strategy 2006* designates large areas of Redland City as statutory Koala Habitat Areas (KHA), this only covers 58% of Redland City's koala population. A further 42% of Redland City koalas live in non-statutory urban Koala Living Areas (KLA) yet these koalas are believed to make a significant contribution to the overall koala population. Evidence suggests that the bushland koalas cannot persist without urban koalas and that "bushland habitat on its own is not sufficient to maintain the Koala Coast koala population" (EPA 2007).

In order to protect Redland City's koalas, the Redland City Council has developed a *Koala Policy and Strategy 2008* which addresses seven key issues:

1. Impacts of urbanisation and its future growth on the koala population
2. Road and rail koala deaths
3. Dog attacks on koalas
4. **Protect, enhance and increase koala habitat**
5. Improve koala movement through neighbourhoods and backyards
6. Increase commitment to funding koala research and monitoring
7. Create a 'Koala Active Community' which understands its role in the long term survival of koalas and takes positive action to fulfil this

In order to "**protect, enhance and increase koala habitat**" it is important that RCC has reliable information on the distribution, abundance and condition of existing koala habitat (Bryan 1997).

2.1 What is koala habitat?

Food Resources

Koalas are arboreal foliovores. The *Queensland Nature Conservation (Koala) Conservation Plan and Program 2006* defines a tree as that which is of a height greater than 4m or a diameter at breast height (dbh) greater than 10cm. The policy further specifies that 'koala habitat trees' are those which belong to the *Angophora, Corymbia, Eucalyptus, Lophostemon* and *Melaleuca* genera however species within these genera are not necessarily koala food trees. Redland City Council's Vegetation Enhancement Strategy (VES) classifies koala food trees as either primary or secondary (**Table 1**). Furthermore, *Eucalyptus tereticornis, E. microcorys* and *E. propinquia* are known to be preferred by koalas throughout Queensland and Redland City (Martin and Handasyde 1999, Davis 2008).

More localised variation in feeding preferences may also occur due to inter and intra specific variation in leaf quality. Leaf quality is determined by the level of toxic compounds (secondary plant metabolites) and the ratio of these toxins to nutritional content (Martin and Handasyde 1999 and Creagh 1992). Leaf quality is also affected by soil characteristics such as the soil nutrient balance, moisture content and drainage and koalas are known to prefer trees that grow on soils that are fertile, well watered and well drained (Creagh 1992).

Table 1 Primary and Secondary koala food trees

PRIMARY	SECONDARY	
Eucalyptus microcorys	*Corymbia citriodora*	*Eucalyptus nicholli*
Eucalyptus racemosa	*Corymbia intermedia*	*Eucalyptus resinifera*
Eucalyptus robusta	*Eucalyptus carnea*	*Eucalyptus siderophloia*
Eucalyptus seeana	*Eucalyptus crebra*	*Eucalyptus tindaliae*
Eucalyptus tereticornis	*Eucalyptus fibrosa*	*Lophostemon confertus*
Eucalyptus propinqua	*Eucalyptus major*	*Lophostemon suaveolens*
	Eucalyptus moluccana	*Melaleuca quinquinervia*

The influence of soil characteristics and hydrology on leaf quality explains why the food resources in many of the Redland's urbanised coastal areas are thought to be preferable to those in larger patches of inland bush. Coastal soils in these areas are often more fertile deep red soils (land zone 5) or alluvial soils (land zone 3) and are often found in association with accessible groundwater which also brings leached nutrients closer to the surface (Newlands 2008). The prime location and workability of coastal agricultural soils also makes them highly susceptible to development whilst the less fertile, stony inland soils are left as extensive patches of bushland. In Coffs Harbour the largest numbers of koala sightings and good quality habitat occur in areas with the highest concentration of people as "the distribution of koalas in this area is a reflection of their habitat requirements for flat, fertile land; for the same reason, this is also the area where people prefer to settle" (Lunney *et al.* 2000). Similarly, most of Noosa's remaining intact koala habitat occurs within State Forest and National Park in areas with infertile sandy soils which reduce the quality of these food resources for koalas (McAlpine *et al.* 2006).

Micro-variation in soil characteristics may also explain why koalas often exhibit strong preferences for one of two neighbouring trees of the same species. It is common to see one tree heavily utilised by koalas (as evidenced by heavy browsing and numerous scratch marks) whilst a neighbouring tree of the same species remains untouched. Seasonal feeding preferences have also been observed. This is likely due to the influence of seasonal environmental conditions on leaf quality (Martin and Handasyde 1999).

Shelter and Stepping Stone Trees

Koalas generally feed during the night and sleep for most of the day yet diurnal tree use does not necessarily correlate with nocturnal feeding habits. Day time tree preferences may be influenced by climatic conditions. On very hot and cold days in Victoria, koalas show preference for shady trees with dense foliage such as *Banksia, Acacia* and *Melaleuca* and "only move into preferred food trees during the cool of night" (Martin and Handasyde 1999). Redland City Council's Wildlife Officer, Jennifer Davis, also reports that Redland City's urban koalas often use shady Poincianna and Mango trees during the day time. Furthermore Joe Friend (2008) reports that the koalas around Lismore have been seen using Camphor Laurel (*Cinnamomum camphora*) trees and the researcher has also witnessed Cleveland's koalas in *Casuarina* trees.

Koalas have 'home ranges' which are areas within which they regularly move about to perform their daily activities (Formon and Godron 1986). As koalas move throughout their home range they often use non-food trees as 'stepping stone trees' (Davis 2008). These stepping stone trees are important as they provide protection from the threats of dogs and traffic, link fragmented patches of habitat, and facilitate dispersal which is vital to maintain genetic diversity.

2.2 Koala Habitat Assessment

There are many ways to define and assess 'koala habitat'. Steve Phillips, from Biolink Ecological Consultants, assesses *actual* koala habitat by scoring the koala activity (as indicated by the presence and abundance of koala scats) in regular samples of 30 trees. To assess *potential* koala habitat Phillips (2008) uses the same sampling method but instead records the percentage contribution of preferred food trees. From this information, Phillips classes the koala habitat quality of vegetation communities as either: primary (more than 50% food trees), secondary (less than 50% food trees) and non-habitat (no food trees). This assumes that vegetation communities dominated by preferred food trees support healthy, viable koala populations whereas vegetation communities dominated by non-preferred species do not support healthy, viable koala populations even though the latter may be used as temporary habitat (Bryan 1997). This assumption is not always true as potential koala habitat does not always correlate with actual koala habitat (Phillips 2007).

Lunney *et al.* (2000) assessed koala habitat in Coffs Harbour using community and field surveys of koala activity, vegetation communities and geology and found that koala activity levels were significantly higher in *E. microcorys* trees and on quaternary geological deposits. Lunney *et al*. (2000) describes prime koala habitat as vegetation units on quarternary deposits which contain *E. microcorys*. Bryan (1997) also argues that assessment of koala habitat suitability requires information on dominant vegetation and soil property indicators.

The EPA (2006) recommends transect surveys of koala presence and abundance as the most reliable method of habitat assessment as "*other indicators of good koala habitat such as soil and foliage analysis or species of tree present are too conflicting to consider as reliable methods".* Dique *et al.* (2004) employed this method to estimate the population of bushland and urban Koala Coast areas. The transect method was used in conjunction with complete surveys of private properties within urban areas of the suburbs of Cleveland, Thorneside and Capalaba.

3.0 Project Aims

Assessments of koala habitat have largely ignored the individual trees of urban forests yet it is suggested that the quantity and quality of urban koala habitat has been severely impacted upon by *"the cumulative affect of losing individual trees on residential lots, the removal of roadside vegetation for road upgrades or the development of remnant patches of vegetation for housing estates and commercial precincts*" (EPA 2007). Aerial photography and general observations suggest that Redland City has many trees however very few of these appear to be suitable koala habitat or food trees as Newlands and Duant (2007) found that only 10% of Ormiston's street trees were natives and less than 5% of these were koala food trees. These figures are well below Council's VES policy commitment for "100% locally native and/ or Australian native species in Council managed lands including streetscape plantings" and the Queensland nature conservation policy recommendations for "70% Australian plants of which 50% are native to the area including Koala habitat trees were practicable".

The Cleveland pilot study therefore aimed to investigate:

- The average abundance of trees per hectare and the percentage contribution of locally native, Australian native and exotic tree species; and
- The average abundance and percentage contribution of koala habitat trees, koala food trees and preferred koala food trees per hectare.

Furthermore, a Green Infrastructure Plan for urban koala corridors has been initiated using desktop analysis of aerial photography hence the pilot study also aimed to answer the following questions:

- Is there a significant difference in the average abundance of desktop trees and actual trees?
- Is there a correlation between the abundance of desktop or ground truth trees and koala habitat trees?

The methodology and results of the pilot study to date are detailed in this report along with a review of the chosen methodology, discussion of results and recommendations.

4.0 Methodology

4.1 Study Area and Sampling Techniques

The suburb of Cleveland was chosen for the pilot study due to the time and transport limitations of the researcher. Land use planning zones were used to stratify random samples of one hectare plots. Land use planning zones are "*used by urban planners to control the physical characteristics of developing landscapes by imposing restrictions on variables such as maximum building height and density, extent of impervious surface and open space, and land use types and activities"* (Wilson *et al.* 2003) hence it was thought that they may account for some of the variation in urban tree abundance. Zones which contributed less than 0.5% of the area of Cleveland were excluded. The following zones were therefore used to stratify the sample selection: Urban Residential (UR), Medium Density Residential (MDR), Open Space (OS), Conservation (C), Major Centre (MC), Community Purpose (CP), General Industry (GI), Commercial Industry (CI), Environmental Protection (EP), Marine Area (MA) and Low Density Residential (LDR).

After initial experiments with manual random sampling (**Appendix A**) it was decided that an automated random sampling process was necessary. ArcMap was used for this purpose and Hawth's Spatial Ecology 'Create Vector Grid Tool' (http://www.spatialecology.com) was used to generate a spatially referenced grid layer across Redland City's LGA.

ArcMap's 'Select by Attribute' and 'Select by Location' tools were used to create 11 new grid layers each representing the hectares within Cleveland that have their centre in each of the respective land use planning zones. For example, a grid layer of hectares with their centre in the UR zone was created. The new grid layers were then manually screened to ensure that the grids did not contain hectares with:

- more than 10% of another suburb
- more than 10% of another land use planning zone
- more than 10% of non-terrestrial cover such as canals, creeks, mudflats and mangroves

The main problem with this sampling method is that some hectares which contained only the land use planning zone of interest were omitted because there centre fell within in a road reserve. To overcome this it is recommended that future grid generation use that 'select features which contain' command to select all hectares which contain the land use planning zone of interest, however this will require more intensive screening to remove hectares which are dominated by other land use planning zones.

Random samples were selected from within each planning zone grid layer using Hawth's random sampling tool with the number of samples per zone in proportion to each zone's percentage contribution to the total area of Cleveland. 100 ha were chosen in total however only 74 desktop samples and 25 ground truth samples were completed. Desktop analysis of the Conservation (C) zone was not done as the 2006 aerial photography showed that this zone has 100% tree cover.

Table 2. Area contribution of land use planning zones and proportional sampling distribution.

Land use planning zone		Ha	%	Intended samples	Actual desktop samples	Actual field samples
Urban Residential	UR	330.65	34	34	**15**	**11**
Medium Density Residential	MDR	177.66	18	18	**23**	**10**
Open Space	OS	112.91	12	12	**11**	-
Conservation	C	112.69	11	11	-	-
Major Centre	MC	97.28	10	10	**7**	**4**
Community Purposes	CP	66.36	7	7	**8**	-
General Industry	GI	37.92	4	4	**4**	-
Commercial Industry	CI	16.59	2	2	**2**	-
Environmental Protection	EP	8.55	<1	1	**1**	-
Marine Activity	MA	8.13	<1	1	**2**	-
Low Density Residential	LDR	5.71	<1	1	**1**	-
Unzoned	U	3.56	<0.5	-	-	-
Local Centre	LC	2.46	<0.5	-	-	-
Park Residential	PR	0	0	-	-	-
Emerging Urban Community	EUC	0	0	-	-	-
Neighbourhood Centre	NC	0	0	-	-	-
District Centre	DC	0	0	-	-	-
TOTAL		980.48	100	100	74	25

4.2 Desktop analysis

Desktop analysis was undertaken using Redland City's 2006 aerial photography in ArcMap. ArcMap's zoom tool was used to magnify the sample sites and identify individual trees. Every clump of vegetation that appeared to be a 'tree' in the aerial photography was marked with a 'tree point' in a newly created tree layer shape file. Discerning trees (> 4m high or > 10cm dbh) from shrubs (< 4m high or <10cm dbh) proved difficult and relied on visual cues such as whether or not the canopy overhung buildings and vegetation or, by comparing the vegetation's shadow with the shadows of other landscape elements such as buildings, street posts, cars. Other difficulties included the effect of taller landscape elements overhanging and casting shadows on smaller trees. Some trees also had oddly shaped canopies which made them look like multiple trees whilst groups of close trees appeared as one. Many trees had a distinct palm-like canopy colour and texture and the numbers of these trees were recorded as 'palms' as they are thought to be unsuitable for koala habitat. This process took an average of 20 mins per site.

4.3 Fieldwork

Initial field work relied on a Personal Digital Assistant (PDA) for data capture using the GIS application ArcPad. Digital data capture was chosen because it was thought that this would:

- facilitate koala habitat tree identification and mapping,
- facilitate data storage
- reduce time spent on post fieldwork data entry
- provide an opportunity to initiate a computerised tree inventory

Despite these potential benefits numerous difficulties were experienced with the PDA and paper based data capture (Appendix F and G) was found to be more efficient and user friendly.

Both digital and pater based data capture were facilitated by using print outs of each site's aerial photography and ground truth tree points. As desktop tree points were ground truthed, or new trees were identified, they were marked off on the aerial photograph printouts. Koala habitat trees were marked with a blue circle and a reference number under which the species, height, dbh, health, level of dieback, presence epicormic growth and mistletoe, location and proximity to powerlines, canopy loss and the presence of koalas, scratches or scats. Koala habitat tree species were identified using field guides and where the researcher was uncertain, and the tree was not on private property, specimens were collected and brought to Reserves Officer, Leo Newlands, for verification. Trees above 4m are considered 'koala habitat trees' (EPA 2006) whilst those higher than 10 m are reported to be preferred by koalas (Newlands and Daunt 2007). An assessment of tree health was made using the criteria set out by Nowak *et al.* (No date) (**Appendix B**). Trees that were somewhere between 'good' and 'poor' were considered to be 'fair'. The level of dieback and epicormic was also recorded as this indicates the protracted decline of a tree's health and vigour (Heatwole and Lowman 1986). The degree of mistletoe infestation was also recorded as the researcher had previously noticed numerous park and street trees with mistletoe infestations. Newlands and Daunt (2007) found that street koala food trees had suffered an average of 23% canopy loss due to powerlines hence the percentage canopy loss and proximity of koala habitat trees to powerlines was also recorded. Presence and evidence of koalas was also recorded in the form of koala sightings, scratches and scats. An assessment of significance was also made using the significant vegetation criteria under Local Law No. 6 (RSC 2003) (**Appendix C**).

Non-koala habitat trees were marked with a green tick and circle and species which were known to the researcher were recorded at 19 of the 25 sites. Palms which were not known to the researcher were recorded under 'other palms' and all other unknown trees were classed as 'unidentified'. This helped to ensure that all non-koala habitat trees were counted and provides some preliminary information on tree biodiversity. Non trees were also marked: Shrubs (<10cm dbh or <4 m tall) were marked with an orange 'X', dead trees a brown 'X' removed trees a red 'X', and other 'non trees' a green 'X'. Removed trees were those which had clearly been removed since the 2006 photography whilst other 'non trees' were desktop tree points which formed part of the canopy of a previous ground truth tree. Tree points that were obscured from view by buildings or vegetation were classed as 'not visible' and were marked with a brown '?'.

Field work required more time than anticipated. Six days were scheduled to ground truth the 74 desktop sites, however initial ground truth work at 10 sites required the best of two days. In order to meet the project deadline the ground truth target was reduced. Statistician James McBroom recommended a minimum of 10 sites per zone to perform a GLM ANOVA on uneven replicates. A new target was set to ground truth a total of 11 MDR and 10 UR hectares as these zones were considered to be the most important with regard to koala habitat and food trees in the backyards of Cleveland. Four MC sites had already been ground-truthed at this stage so a total of 25 hectares of Cleveland were ground-truthed.

4.4 Post field work data entry and editing

Paper based and digital data were transferred to excel spreadsheets for analysis in SAS. It was initially expected that the digital data collected in ArcPad could be easily transported from ArcMap into an excel file however experience proved otherwise. Entry of paper based data was much more efficient as only one tree attribute could be copied from ArcMap into excel at any one time, however the former required time to record this information in ArcMap.

4.5 Statistical analysis

Statistical analysis was conducted using the software package SAS (Statistical Analysis System). A GLM ANalysis Of VAriance (ANOVA) was completed on the abundance of desktop and ground truth trees, palms and koala habitat trees. A GLM ANOVA is used to analyse the variance between samples when the number of replicates are uneven (Der and Everitt 2002). Due to the requirement for a minimum of 10 replicates per treatment (McBroom 2008) statistical analysis of desktop results only included the UR, MDR and OS zones, whilst statistical analysis of ground truth results only compared the UR and MDR zones.

A Wilcoxon test was also undertaken determine whether or not desktop tree and palm tree abundances accurately represent the abundance of ground truth trees and palms. The Wilcoxon test was chosen because it is designed for paired data (Chaseling 2006). Regression analysis was undertaken to assess the relationship between desktop tree and ground truth tree abundances with koala habitat tree abundance.

5.0 Results

5.1 Desktop analysis results

Desktop analysis of tree abundance across the MDR, UR, OS, MC, CP, GI, CI, EP, MA, LDR zones recorded a total of 3747 trees and an average of 50.63 trees per hectare. 16% of these trees were thought to be palm trees. The average abundances of desktop trees between the MDR, UR and OS were not significantly different (see **Figure 1 and 2**).

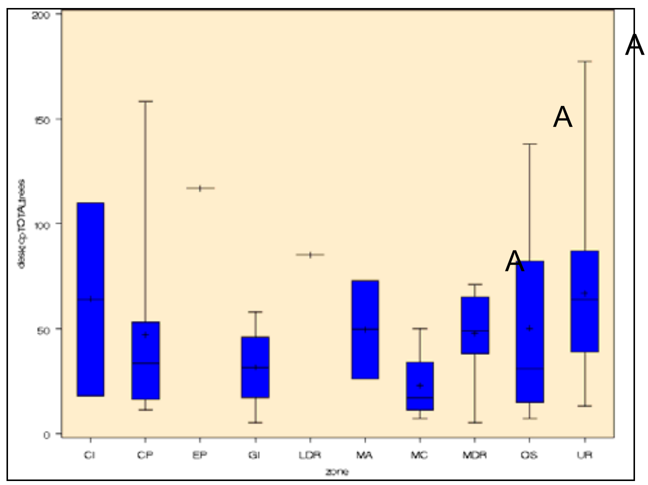

Figure 1. Variation in Desktop Trees across zones in Cleveland: Commercial Industry (CI), Community Purpose (CP), Environmental Protection (EP), General Industry (GI), Low Density Residential (LDR), Marine Activity (MA), Major Centre (MC), Medium Density Residential (MDR, Open Space (OS) and Urban Residential (UR). Zones with the letter A are not statistically different, zones with no A have not been statistically compared due to insufficient sampling.

The abundance of palms in the UR zone was significantly higher ($P<0.05$) than in OS, yet there was no significant difference in palm tree abundance between the UR – MDR and OS – MDR zones (ns).

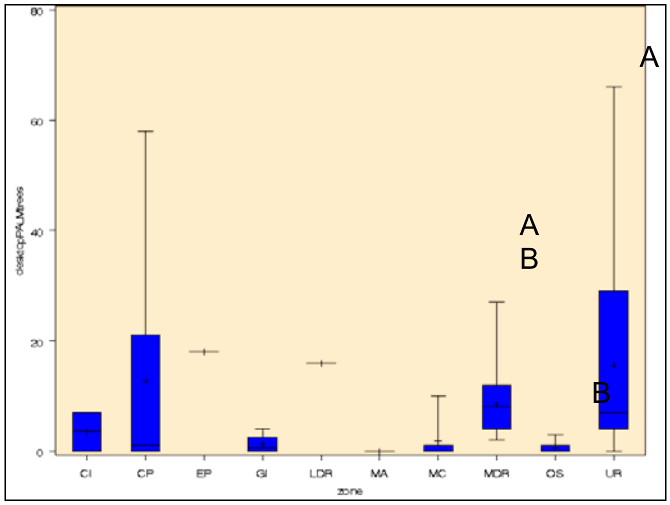

Figure 2. Variation in Desktop Palm Trees in Cleveland: Commercial Industry (CI), Community Purpose (CP), Environmental Protection (EP), General Industry (GI), Low Density Residential (LDR), Marine Activity (MA), Major Centre (MC), Medium Density Residential (MDR, Open Space (OS) and Urban Residential (UR). Zones with the same letter (either A or B) are not statistically different. Zones with different letters are significantly different. Zones with no letter have not been statistically compared due to insufficient sampling.

5.2 Field work results

Field work surveyed a total of 11 Medium Density Residential, 10 Urban Residential and four Major Centre hectares and 1359 desktop trees and 1348 ground truth trees were recorded across this 25 hectare sample. Although 25% of the desktop 'tree points' were found to be 'non trees' these were replaced with a similar number of new trees which were not visible in the 2006 aerial photography. The average abundances of desktop trees (54.36) and ground truth trees (56.6) were therefore not significantly different. The 'non trees' consisted of 149 shrubs, two dead trees, 77 not visible trees, 80 removed trees and 31 other 'non trees'. The removal of 80 trees over the two year period equates to a 6% loss of the potential tree population. The majority of removed trees occurred in the MDR zone as 23 trees were lost from two large properties which were cleared for the construction of a multi-storey apartment block. Local resident Bob Stubbs recalls that many of these trees were big eucalypts. One large *Eucalyptus tereticornis* remains standing on the perimeter of this construction site and it is of notable significance due to aesthetics, height and trunk diameter and important koala habitat as the trunk has been well scratched by koalas.

Desktop analysis appeared to underestimate the abundance and percentage contribution of palms as 309 desktop palms (23% of all desktop trees) and 488 ground truth palms (33% of all ground truth trees) were recorded. Never the less, the average abundance of desktop (14.5) and ground truth (20.55) palms were not significantly different

No significant difference was found in the average abundances of ground truth trees between the MDR (48.18) and UR (68) zones (**Figure 3**) however the average abundance of palms was significantly different ($P < 0.05$) between the MDR (9.636) and UR (32.1) zones (**Figure 4**).

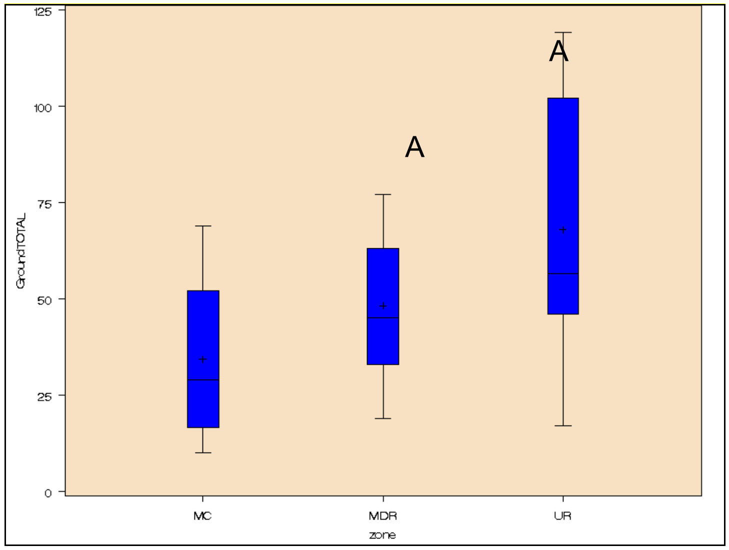

Figure 3. Ground truth tree abundances by land use planning zones MC, MDR and UR. Zones with the same letter are not significantly different. Zones without a letter have not been statistically compared.

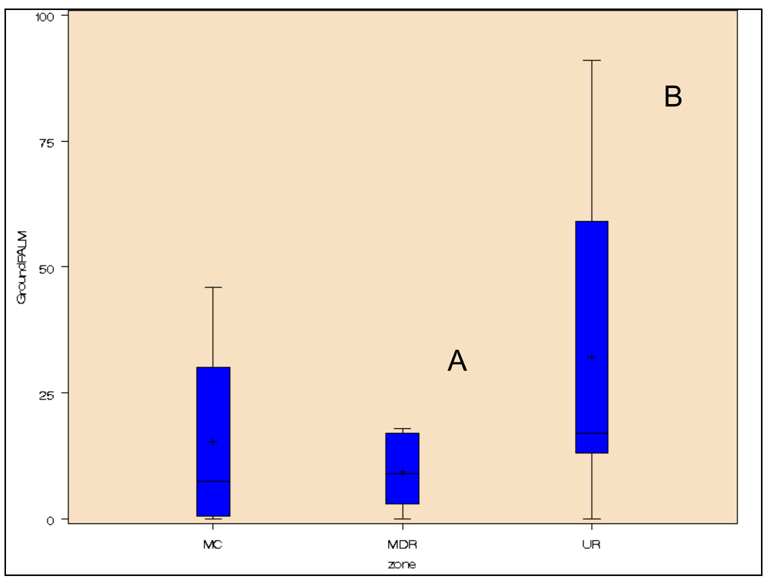

Figure 4. Ground truth palm tree abundances between MC, MDR and UR zones. Zones with different letters are significantly different. Zones without a letter have not been statistically compared.

Biodiversity

1050 ground truth trees occurred across the 19 sites in which all known trees were recorded. Only 16% of these trees were locally native, another 30% were other Australian natives however 39% were exotics. A further 15% were not identified (**Figure 5**).

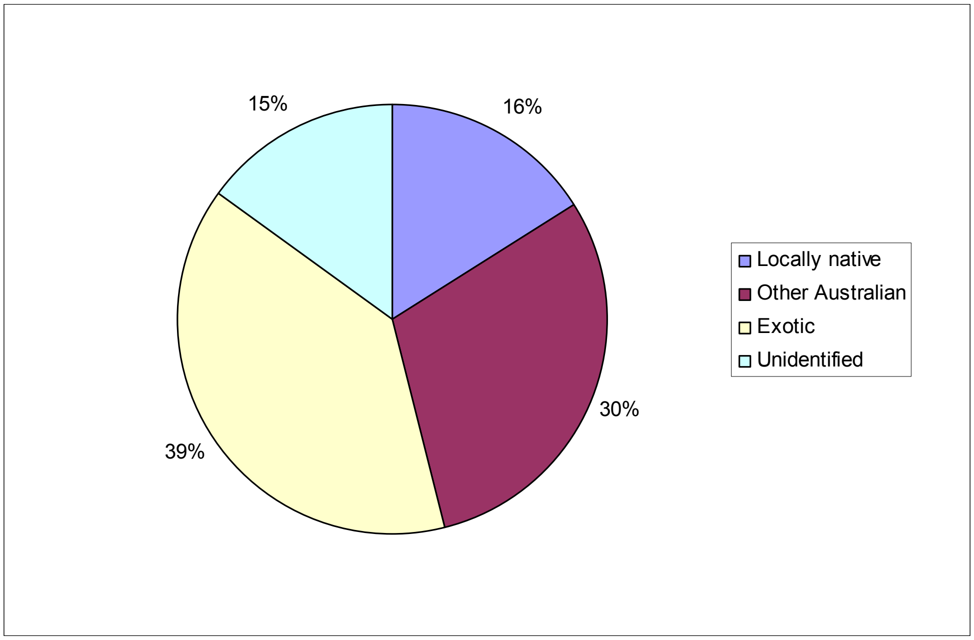

Figure 5. Contribution of locally native, other Australian and exotic species.

Palm trees made up 34% of all trees and approximately half of these were the Australian Alexander palm (*Archontophoenix alexandre*). The Alexander palm was also the most common tree overall as it made up 18% of all trees across the 19 hectare biodiversity sample. The Madagascan Golden Cane palm (*Dypsis Lutescens*) was next most common contributing 12% of all trees. 'Koala habitat trees' collectively contributed 10%. Five percent of all treeswere unknown palms whilst another 5% were the weed listed Brazilian Cocos palm (*Syagrus romanzoffiana)*. Other common trees contributing more than 1% included the Poincianna, Small Leaved Lilly Pilly, Weeping Bottlebrush (*Callistemon viminalis)*, Leopard Tree (*Caesalpinia ferrea)*, Mango (*Mangifera sp.),* Silky Oak (*Grevillea robusta)*, Tulipwood *(Harpullia pendula)* , Jacaranda (*Jacaranda mimosifolia)*, Umbrella *(Schefflera actinophylla)* and Frangipani (*Plumeria rubra*) (**Figure 6**).

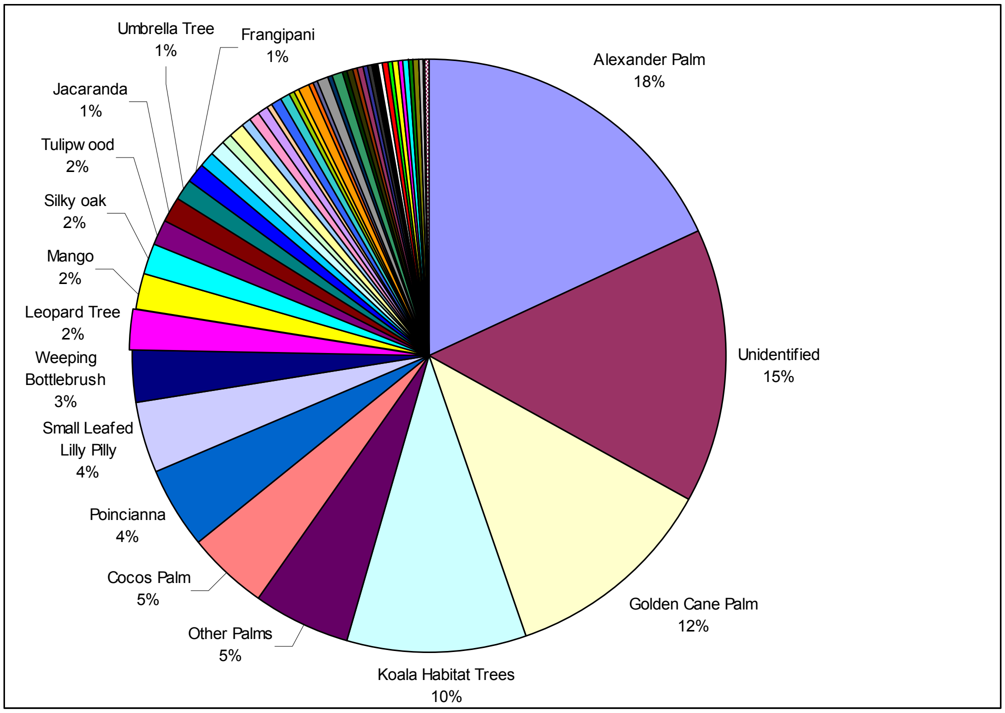

Figure 6. Tree biodiversity of 19 hectares of the 25 hectare ground truth sample.

5.2.1 Koala habitat trees and preferred food trees

124 koala habitat trees were recorded contributing to 9% of the 1415 ground truth trees recorded across the 25 hectare MDR, UR and MC ground truth sample. The average number of koala habitat trees per hectare was 4.96 however many of these were melaleucas with single species, *Melaleuca bracteata,* contributed to one third of all koala habitat trees. One in every three of these was the sterile Revolution gold variety. Less than half of all koala habitat trees were primary or secondary food trees (**Figure 7**) hence only 4% of all ground truth trees were either primary or secondary preferred food trees.

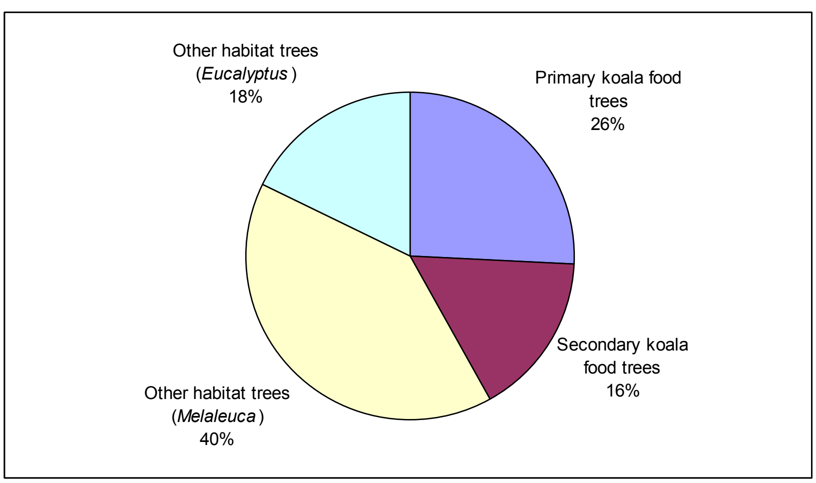

Figure 7. Contribution of primary and secondary food trees to koala habitat trees.

Most of the primary food trees were also preferred food trees such that both primary and preferred food trees made up only 2% of all ground truth trees. Most of the primary and preferred feeding trees were Queensland blue gums (*E. terreticornis)* (**Table 3**). The average number of preferred food trees per hectare was 1.12. Table 5 Koala habitat tree species contributions

Koala Habitat Trees							
	Species	**Common name**	**UR**	**MDR**	**MC**	**TOTAL**	**% of all habitat trees**
Preferred food trees	***E. microcorys***	**Tallow wood**	**3**	**0**	**3**	**6**	**5%**
	E. propinquia	**Grey gum**	**0**	**1**	**0**	**1**	**1%**
	E. tereticornis	**Forest red gum**	**3**	**18**	**0**	**21**	**17%**
Other primary food trees	*E. racemosa*	Scribbly gum	1	0	0	1	1%
	E. robustus	Swamp mahogany	1	0	0	1	1%
	E. seanna	Narrow-leaved red gum	1	1	0	2	2%
Secondary food trees	*Corymbia citriodora*	Lemon scented gum	1	0	0	1	1%
	Lophostemon suaveolens	Swamp box	2	0	0	2	2%
	M. quinquinervia	**Broad leaved paperbark**	**8**	**9**	**0**	**17**	14%
Other eucalypt habitat trees	*E. curtisii*	Plunkett Mallee	2	0	0	2	2%
	E. pilularis	Blackbut	1	0	0	1	1%
	E. ptychocarpa	Swamp bloodwood	1	1	0	2	2%
	E. saligna	Sydney blue gum	1	3	0	4	3%
	E. sp	Eucalypt	3	0	0	3	2%
	E. tesselaris	Moreton Bay Ash	4	1	0	5	4%
	E. torrelliana	Cadahgi	4	1	0	5	4%
Other melaleuca habitat trees.	***M.bracteata***	**Black tea tree**	**15**	**10**	**1**	**26**	21%
	M. bracteata	**Revolution gold black tea tree**	**4**	**6**	**2**	**12**	10%
	M. linarifolia	Snow in summer	3	5	1	9	7%
	M. nodosa	Prickly leafed paperbark	0	1	0	1	1%
	M. sp	Melaleuca	1	1	0	2	2%
	TOTAL		59	58	7	124	100%
	Average / ha		**5.9**	**5.3**	**1.75**	**4.96**	-

The average abundance of koala habitat trees was not statistically significant between the MDR and UR zones (**Figure 8**). Although the UR had the highest average number of koala habitat trees (5.9 / ha) this zone had the lowest average number of preferred feeding trees (0.54 / hectare) (**Figures 9**). Statistical analysis on the difference in preferred food tree abundances between the MDR and UR zones was not undertaken as the data was found to follow a Zero Inflated Poisson (ZIP) distribution (McBroom 2008). No significant correlation between the abundance of koala habitat trees and desktop trees or ground truth trees was found (See **Figure 10 and 11)**.

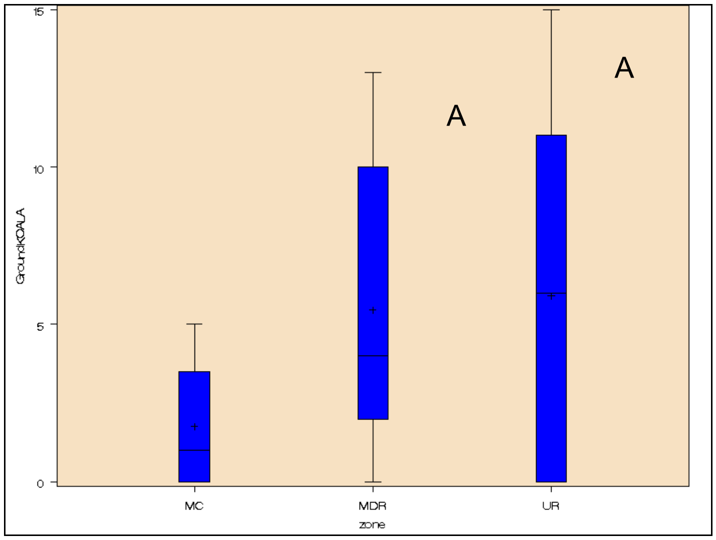

Figure 8. Variation in koala habitat tree abundance by land use planning zones MC, MDR and UR. Zones with the same letter are not significantly different. Zones without a letter have not been statistically compared.

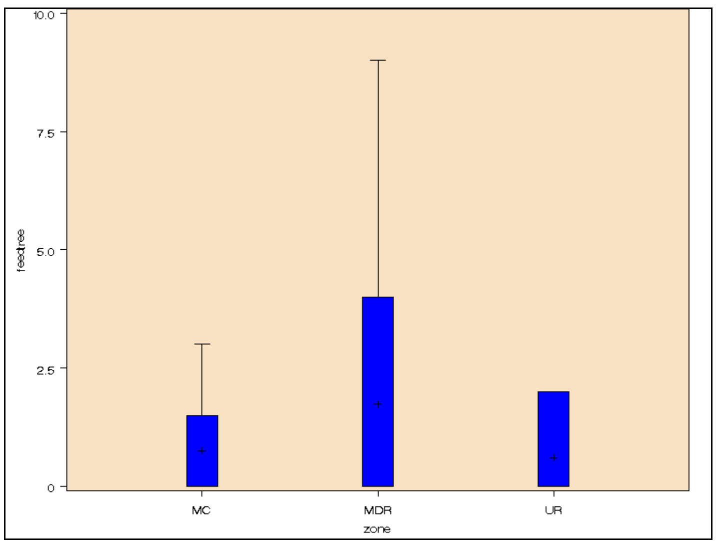

Figure 9. Variation in preferred koala food tree abundance across MC, MDR and UR zones.

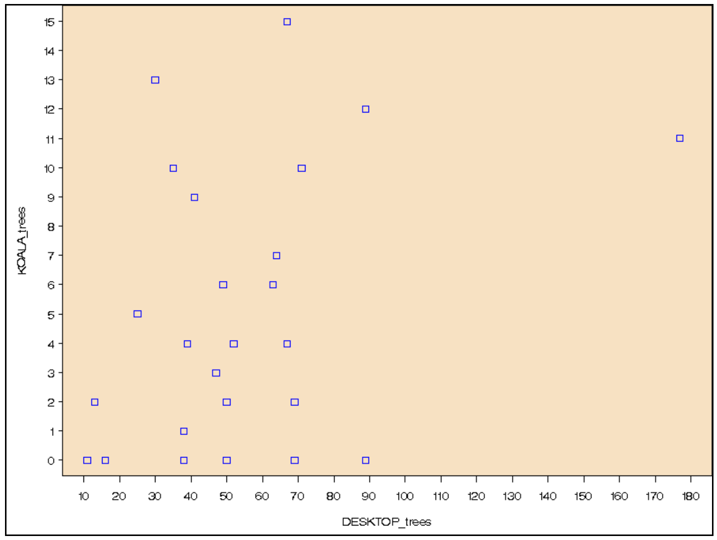

Figure 10. There was no correlation between the abundance of desktop trees and koala habitat trees (P = 0.084).

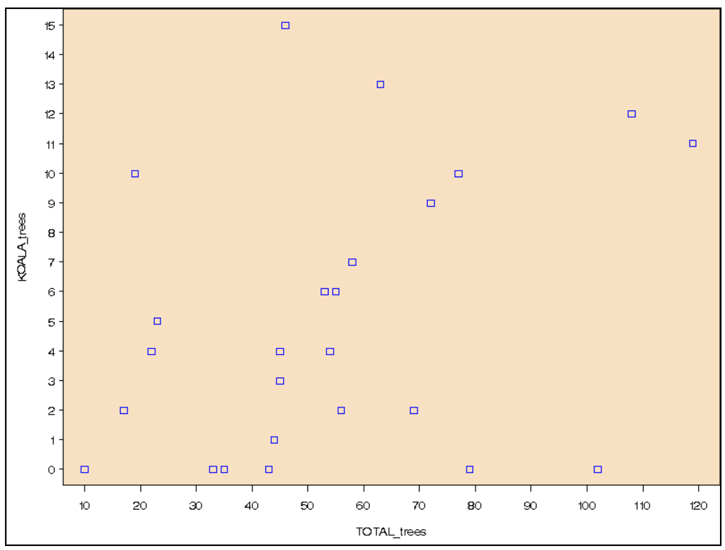

Figure 11. There was no correlation between the abundance of ground truth trees and koala habitat trees (P=0.1035).

5.2.2 Condition of koala habitat trees and preferred food trees

Height

- 22% koala habitat trees and 46% of preferred food trees were taller than 10 m.

Diameter at breast height (dbh)

- 79% of koala habitat trees had a dbh between 10 and 50 cm whilst 59% of preferred food trees had a dbh within this range a further 31% of feeding trees had a dbh of 50 – 100 cm. Four koala habitat trees had a dbh greater than 100 cm for which they were considered significant.

Health

- 19% of koala habitat trees were excellent, 47% in good condition 31% fair and 3% were poor.
- 14% of preferred food trees were excellent, 60% good, 21% fair and 4% were considered to be in poor condition (**Figure 12**)

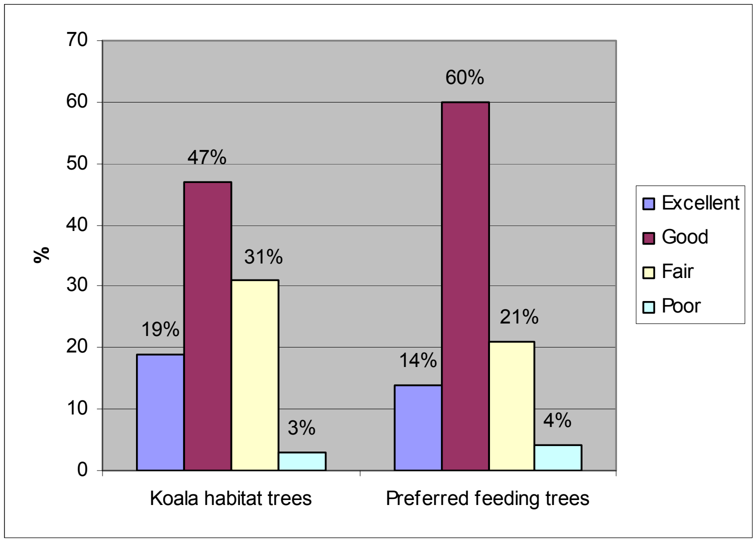

Figure 12. Health of koala habitat and preferred food trees

Dieback and epicormic growth

Minor dieback was noted on 20% of koala habitat trees and 7% of preferred food trees. No preferred food trees had major dieback however 4% of koala habitat trees did and most of these were Melaleuca bracteates. The cause of dieback was only obvious for two preferred food trees: the canopy of one was dominated by noisy minors, whilst the trunk of the other was completely surrounded by a large epiphyte. Epicormic growth occurred on 4% of habitat trees but not in preferred feeding trees.

Location

Approximately half of all koala habitat trees occurred on private property however many of these were not food trees as only one quarter of preferred food trees occurred on private property whilst another quarter occurred in open space and almost half of all trees occurred in road reserves (**Figure 13**).

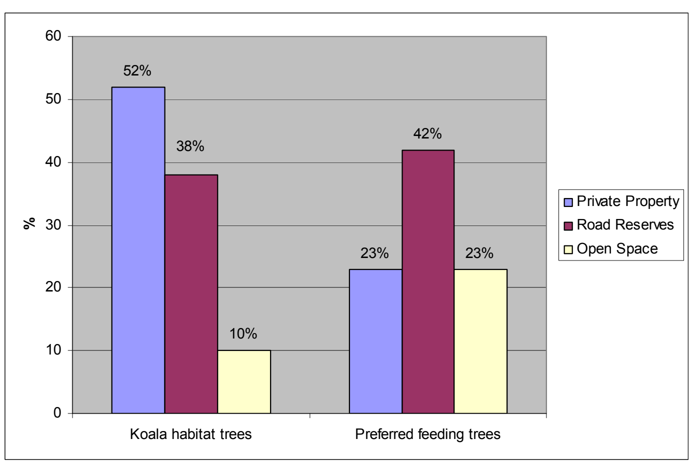

Figure 13. Location of koala habitat and preferred feeding trees

Proximity to Powerlines and Canopy loss

Although approximately one in every there preferred food trees were next to or underneath to powerlines (**Figure 14**) only 13% of habitat trees were found to have some degree of canopy loss however this equalled only 16 trees. Furthermore, canopy loss was not necessarily associated with proximity to powerlines as some canopy loss occurred due to pruning trees which overhung property boundaries. Canopy loss ranged from 30 – 90 % and averaged 60%.

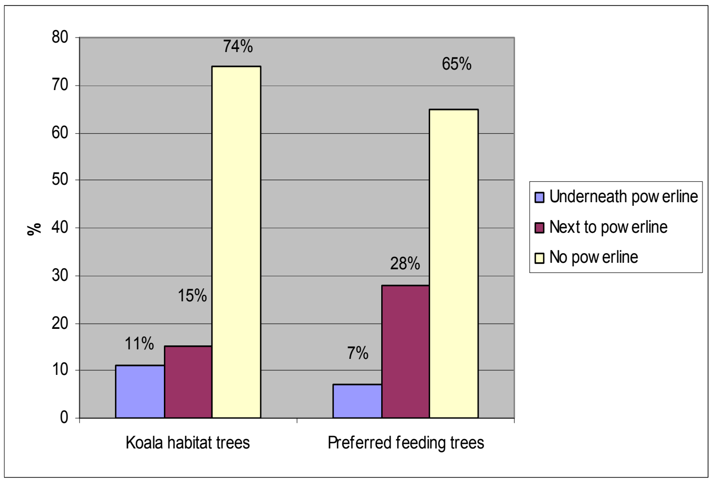

Figure 14 . Proximity to powerlines

Evidence of koalas

No koalas were sighted during the field surveys. Scratches were observed on 38 habitat trees, including 16 of preferred feeding trees. Scats were noted on 18 habitat trees, including eight preferred feeding trees, however this was influenced by scat visibility as the leaf litter was not rigorously sampled.

Scratches and scats were most commonly observed on *E. tereticornis* yet the highest numbers of scats were observed around two *E. saligna* and *E. robustus* trees. Local resident Geoff Hegarty also reported that koalas favour the large 40 year old *E. saligna* in his backyard, however the base of the trunk was too rough and the ground cover too dense to see any scratches or scats. Similarly another *E. saligna* tree, not surveyed during field work, appears to be favoured by koalas due to heavy scratching and frequent numerous scats. Koala scratches and scats were also observed on and around *C. citriodora, E. saligna, E. seanna, E. torrelliana, E. tesselaris and M. quinquinervia.*

Significance

A total of 20 trees were thought to be considered significant, with seven of them being preferred food trees. These trees were thought to classify for significance due to their habitat value (as indicated by numerous koala scratches ands scats or the presence of other fauna such as birds), aesthetics or their height, circumference and dbh.

6.0 Discussion and Recommendations

6.1 Review of methodology

Land use planning zones and insufficient sampling

No significant differences in the numbers of MDR, UR and OS desktop tree and MDR and UR ground truth trees or habitat trees were found. The main problem with using land use planning zones for sample strata is the large amount of variation of desktop tree abundances within zones due to diverse landscape characteristics. For example, OS sites ranged from densely treed to sparsely treed parks and totally treeless sports fields. CP sites also varied from schools, churches and community centres with good tree cover to treeless school sports fields. One of the CP sites was a palm plantation and despite a high abundance of trees, they were all palms. Some of the variation in landscape characteristics is also attributable to discrepancies between the planning scheme and current land use. In the desktop analysis of the Commercial Industry (CI) one site was covered by 25% bushland as the planning zone appears represents the intended future purpose of the land rather than the current land use. The same is true within residential zones as many Medium Density Residential (MDR) properties appear to be of equivalent size to Urban Residential properties and some of these again are the equivalent area of Low Density Residential (LDR) properties. For this reason it may also be valuable to investigate the relationship between the density of properties or dwellings and the abundance of trees, habitat trees and koala feed trees.

Despite these issues, sampling is yet insufficient to conclude that land use zones in general do not influence the variation in tree and habitat tree abundance. Preliminary ground truth work within the MC zone suggests that this zone may have significantly lower numbers of habitat trees yet more replication is required. Also, zones which may have significantly higher number of koala habitat and food trees (Conservation, Low Density Residential Park Residential and Environmental Protection) and zones which may have significantly lower numbers (Commercial Industry, General Industry and Marine Activity) have not yet been sampled either due to time limitations or the lack of these zones within Cleveland. The sampling of these areas may influence the average number of trees, koala habitat trees and preferred food trees per hectare. It is recommended that the next phase of the pilot study is to ground truth at least 10 hectares of each of these zones and determine whether or not they contribute to significant differences in tree, habitat tree and preferred food tree abundance. If so, then the land use planning zones are suitable sample strata and it will be necessary that the numbers of replicates per zone matches the percentage contribution of each zone to the total area of Redland City's urban footprint (**Appendix E**). To ensure that samples are well spread across the urban footprint it is recommended that replicates within suburbs are also proportioned according to the area contribution of each suburb. These figures can be calculated in ArcMap and details of this will be provided in the Project Manual.

Digital Vs Paper based data capture

Despite the potential benefits of digital data capture, paper based data capture was found to be more efficient. Digital data capture was tedious and time consuming as each time a 'tree point' was edited ArcPad had to redraw all the roads, property boundaries, parks and tree layers. Although the redraw time was reduced by limiting these layers to Cleveland, delays were still encountered. The small screen of the PDA also made it difficult to view each hectare in full and, the road, property boundaries and parks layers provided limited visual cues as to which points were what trees. Although the aerial photography could have been uploaded to improve tree referencing, this would have slowed the application down even further. The transfer of digital data from ArcMap to Microsoft Excel was also inefficient as the tree layer's entire attribute table could not be copied and pasted. Data entry from paper tables therefore proved more efficient.

Paper based data capture was also more user friendly. The PDA and ArcPad application require sufficient training, time and practice before one is proficient with these applications. Despite the researcher having prior GIS experience and attending a one day PDA and ArcPad workshop, the researcher still experienced difficulties these applications. Never the less, if further research aims to map all trees surveyed there are two pathways that may be pursued. The first is that paper based data capture is continued, however this will present difficulties in areas with few spatial references such as buildings. In such instances the digital data capture will require the use of a PDA and GPS. If so then the current PDA will need to be altered and the following fields and options are recommended:

- Koala habitat tree? Y / N
- Genera: *Angophora, Corymbia, Eucalyptus, Lophostemon* or *Melaleuca*
- Koala food tree? No , Primary or Secondary
- Species:
- Height: m
- Dbh: cm
- Health: Excellent, Good, Fair, Poor, Dead
- Dieback:
- Koalas: Y or N
- Scratches: 0,1,2,3
- Scats: Not Visible, None, Few or Many
- Significant: No
- Location: Private Property, Open Space, Road Reserve
- Powerlines: Y or N
- Canopy Loss: %

To make data capture more efficient it would be useful to limit species identification to koala food trees as listed under the VES. The genera of other koala habitat trees may be sufficient. To facilitate the process of tree identification it is also recommended that the researcher take prior training to become proficient in the identification of all locally native and koala food tree species listed under the VES.

Desktop analysis and Fieldwork issues

Whilst ground truth work found that many desktop trees were 'non trees' it also identified many new trees that were not distinguishable in the aerial photography. This was because they were either underneath the canopy of taller trees, were overshadowed by taller neighbouring trees, or were not yet large enough to be considered a 'tree'. Desktop analysis also often underestimated the abundance of palms as they generally occurred in dense clumps and so appeared as one in the aerial photography. Banana trees were also found to have a similar canopy texture to palms and hence were often mistaken as palms during desktop analysis.

The deficiencies of the desktop analysis and the field survey methodology were highlighted by site MDR 28663. Whilst desktop analysis recorded a total of 41 trees, field work recorded 72 trees. Many of these trees would not have been recorded if resident Geoff Hegarty had not invited the researcher to view the trees from the backyard. Furthermore, two eucalypts would not have been accurately identified had this opportunity not occurred. This highlights the difficulties of counting and identifying trees from the footpath. Footpath-based surveys also meant that numerous koala habitat tree attributes were omitted. 52% of all habitat trees occurred on private property and, unless they were on the footpath boundary, the base of the trees was not accessible hence dbh or the presence of koala scratches and scats could not be recorded. Despite this deficiency the only alternative of this method is to gain access to private properties however this process would be resource and time intensive and, residents, particularly those who are already thinking about cutting down the trees in their yard, may be reluctant to comply. It is for these reasons that footpath based tree surveys were undertaken.

Definitions of koala habitat trees and preferred koala food trees

Although all ground truth trees (> 4m high or 10cm dbh) classified as koala habitat trees under the *Queensland Nature Conservation (Koala) Conservation Plan and Policy 2006* criteria many of these trees were palms and are thus unsuitable for koala habitat. Although it is necessary that the numbers of koala habitat trees and preferred food trees be considered in terms of the percentage of all ground truth trees, future assessments of 'koala habitat trees' should consider the total number of ground truth trees minus the number of palm trees.

The assessment of preferred food trees was also limited to trees belonging to the species *E. tereticornis, E. microcorys* and *E. propinquia* however results suggest that Cleveland koalas may also preferentially feed upon *E. saligna* and *E.robusta*. These observations may be a result of localised variation in soil characteristics, environmental conditions and tree genetics on leaf quality (Martin and Handasyde 1999).

Statistical Analysis

SAS was chosen for the statistical analysis component of this project because it was readily available through the university and the researcher was experienced in its operation. Redland City Council does not currently have access to statistical software and the continuation of this project will therefore require that the future Project Officer has access to and experience in a statistical software program. SAS would be preferable as the code and instructions for this analysis will be written into the project manual, however it is not essential, as long as the Project Officer has the skills to undertake the same analysis with another software package.

6.2 Review of results and recommendations

The Cleveland pilot study to date shows that, within the MDR, UR and MC zones, the percentage of locally native and other Australian native trees is well below the targets specified by Council' VES and the Queensland *Nature Conservation (koala) Conservation Plan 2006 and Management Program 2006 – 2016* (**Figure 15**).

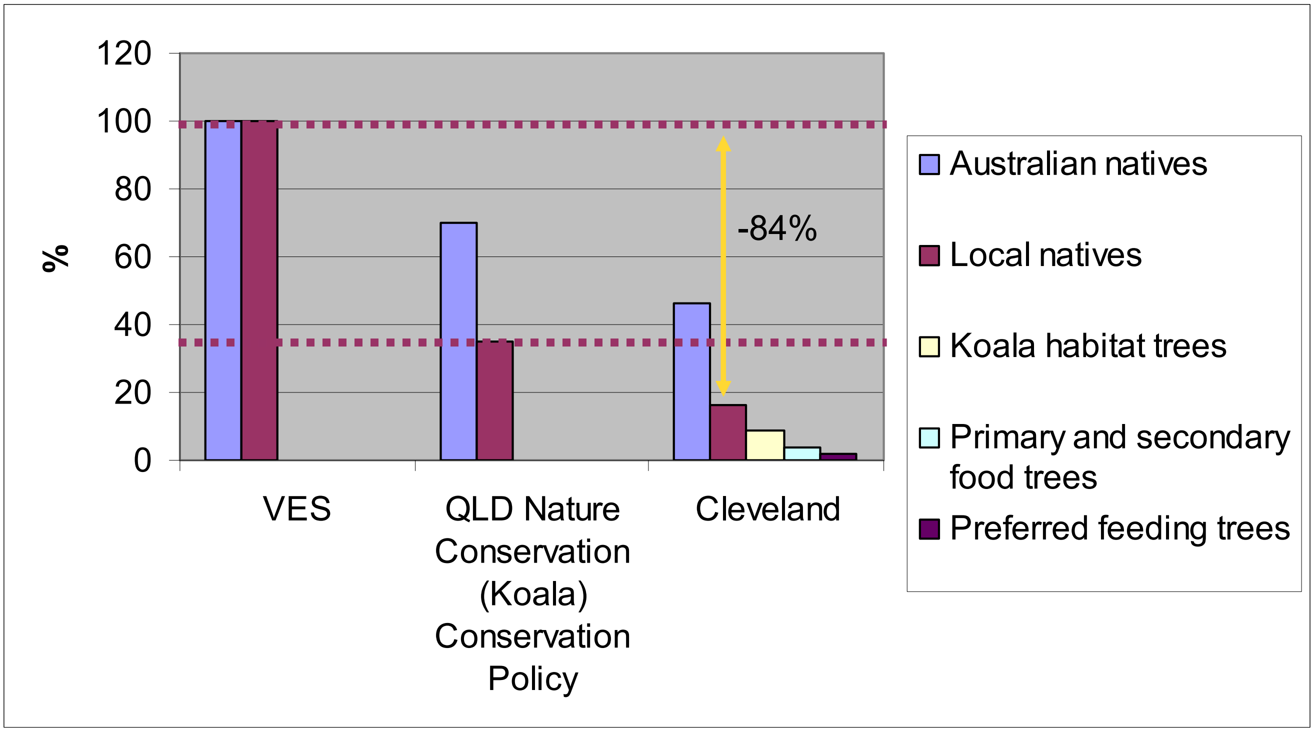

Figure 15. Is Redland City Council meeting its policy commitments?

The abundance and percentage contribution of koala habitat (9%) and food trees (4%) and preferred feeding trees (2%) is extremely low. Variation in soil fertility and leaf quality may also further reduce the availability of food resources. It is there recommended that immediate efforts are made to increase the abundance of these trees on Council managed lands. This work will be of particular importance as climate change may further reduce the quality of these food resources as research by Ivan Lawler from James Cook University shows a negative correlation between atmospheric carbon dioxide and the levels of nitrogen and other nutrients in eucalypt leaves and a positive correlation between atmospheric carbon dioxide and levels of leaf tannins. This means that as atmospheric carbon dioxide increases leaf quality decreases. As a result koalas may need to eat more to get their required protein and nutrients (Roberts 2008). The capacity of an area to support increased browsing will be dependent on the quantity of existing vegetation and its level of primary production. If Redland City Council wishes to preserve the unique situation in which local residents can encounter koalas in their local streets, parks and backyards it is vital that efforts to enhance urban koala habitat are augmented.

Implications for Council's Green Infrastructure Plan

One of Council's initiatives to protect and enhance urban koala habitat is the Green Infrastructure Plan. This plan has so far relied on the 'green patches' of aerial photography to identify urban koala corridors however the non-correlation between the number of desktop or ground truth trees and koala habitat trees suggests that areas of high tree abundance are not necessarily suitable for koala habitat conservation. This highlights that green infrastructure planning must incorporate ground truth work to determine the habitat quality of potential corridors. Beyond the abundance of koala habitat trees and preferred koala food trees, this ground truth work must also consider other habitat quality factors such as the presence of threats including dogs and traffic and barriers to habitat connectivity such as roads and fences (McAlpine *et al.* 2006, Bryan 1997).

Opportunities for koala habitat enhancement

Most of the preferred koala food trees occurred in road reserves or open space adjacent to private property. This highlights that much more can be done to encourage local residents to plant more koala food trees in their front and backyards. In this respect the council has already initiated the Your Backyard Program" to enhance the habitat value of people's backyards that are in or adjacent to corridors which connect parks and reserves. A free garden advice service is available for these people with the aim to help them adopt fauna friendly aspects into their gardens.

Although enhancing the habitat value of resident's backyards must form part of the overall koala habitat enhancement strategy, Council has much more control over the protection and enhancement of trees within road reserves and open space and whilst these trees are vital, they are often an overlooked component of a city's green infrastructure (Scally 2006). In order for Redland City Council to invest in the urban trees for koala conservation it is vital that the other ecological, social and economic benefits of this action are understood. Ecologically, trees enhance biodiversity through the provision of habitat for other wildlife. Other ecological benefits include conservation buffering, prevention of erosion and flash flooding and protection of water quality. Urban trees also play an important role in tackling climate change through carbon sequestration. Strategic planting of urban trees can also make the heating and cooling of buildings more efficient thus helping to reduce greenhouse emissions. Urban trees also enhance quality of life through pollution filtration, visual aesthetics and recreational amenity and are also reported to be associated with reduced levels of stress and illness as well as psychological refreshment and a sense of well being. Economically, trees also contribute to the value of residential and commercial properties and undeveloped land (LTOA 2007). Some of the values of trees have been quantified and assessed in economic terms as the New York City's Neighbourhood Tree Survey surveyed 322 street trees and found that they:

- Store approximately 203 metric tonnes of carbon ($4,100 value)
- Remove 4.3 metric tonnes of carbon / year ($90 value / year)
- Remove 228 kg of pollution per year

(Nowak *et al.* no date)

The London Tree Officer's Association (LTOA) has also developed a method to assess a tree's worth according to its size, health, historical significance and how many people live near to enjoy it. The method is called CAVAT or Capital Asset Value for Amenity Trees (CAVAT) and has been used to estimate the value of ordinary individual trees in London from £8,000 and £12,000 pounds. More special trees valued around 200 000 pounds and the most valuable tree was £750,000 pounds.

In order to calculate the value of trees under the CAVAT method, information on tree species, dbh and health is required. The Cleveland pilot study to date does not provide sufficient information to apply CAVAT as the dbh of habitat trees was recorded in classes of <10cm, 10 – 20cm, 20 – 50cm, 50 – 100cm and >100cm. It is recommended that the CAVAT method be incorporated into the Redlands Urban Tree Project in order to quantitatively assess the value of the urban tree-scape. To achieve this field work will require that the dbh of identified trees are accurately measured.

Further suggestions

Although no koalas were sighted during the surveys this does not mean that koalas are absent from the area (EPA 2006). Sightings of koalas have been recorded throughout Cleveland and other suburbs of Redland City. Residents can report daily koala sightings on a regular basis or can participate once yearly in the koala phone in survey. Although this data gives an indication of the distribution of koalas it does not provide reliable information on the abundance and habitat utilisation of koalas. One possible method for augmenting koala sighting data and community awareness is to establish a koala watch website on which members of the public can record daily koala sightings on an interactive map. Information such as the time and location of the sighting could be recorded as well as tree species (if known) koala activity, size and other comments could all be recorded.

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7.0 Appendices

Appendix A – Experimental sampling techniques

Redland City Council's IT department was requested to produce A1 print outs of Cleveland's 2006 aerial photography and land use planning zones, each overlaid with a one hectare grid. These took sometime to acquire and in the meantime the researcher proceeded with the literature review and experimentation with a desk top selection of one hectare plots using Redland City Council's Red E-Map.

Experimental desktop analysis began by using Red-E-Map to zoom into Cleveland's aerial photography and zooming into random properties to view the tree cover. The measuring tool was used to measure out a hectare and although this boundary was visible in Red-E-Map it did not print. Red-E-Map also contained no tools to mark the locations of trees. To overcome this each site photograph was saved and inserted into a word document. As the hectare boundary did not transfer it was redrawn using Word's rectangular drawing tool. Problems with this method were that Word does not have a coordinate reference or measuring tool and so it is likely that, despite using the Red-E-Map hectare as a reference, the Word based hectare was not accurate. Also each time a new site was selected the magnification differed slightly hence the size of the square differed such that each cut and paste of the hectare square required resizing, which was time consuming.

Initial experiments with desk top tree counting included circling trees by hand on print outs as well as using Microsoft Word's circle drawing tools. Although circling trees by hand was faster, the resolution of printed photographs was poor. Desktop circling therefore increased the accuracy of tree identification and was made more efficient by copying and pasting tree circles.

The land use planning zone map and overlaid hectare grid was used to screen out hectares where more than 10% of the square:

- Fell outside of the Cleveland suburb boundary
- Contained a subdominant land use planning zone, or
- Was non terrestrial (e.g. creeks, canals and tidal areas including mangroves and saltmarshes)

The remaining squares were those for which more than 90% of the square:

- Fell inside of the Cleveland suburb boundary
- Contained only one type of land use zone
- Was terrestrial

In order to randomly select and reference hectare plots the researcher experimented with manually allocating individual reference numbers to each hectare of Cleveland. This approach proved time consuming and too confusing to be done for all of Redland City's Urban Footprint and an automated process was deemed necessary.

Redland City Council's GIS experts were consulted on how to generate a spatially referenced grid in ArcMap. Although this knowledge was not readily available, an internet search revealed that a Create Vector Grid tool is freely available from Hawth's Spatial Ecology Tools for ArcGIS (http://www.spatialecology.com). Hawth's Create Vector Grid tool was used to generate a hectare grid layer over Redland City's Local Government Area (LGA) and within minutes each hectare was spatially referenced with its own unique reference number. This layer was added to the aerial photography and landuse planning zone layers in ArcMap.

Appendix B - Tree Health Criteria

Excellent (E): full well-balanced crown and limb structure; leaves normal size and color; no dead or broken branches; trunk solid; bark intact.
Good (G): crown uneven or misshapen; some mechanical damage to bark or trunk; some signs of insects or disease; leaves somewhat below normal size and quantity; some dead or broken branches
Poor (P): large dead limbs with over one-half of the tree already dead or removed; large cavities; drastic deformities; leaves significantly below normal size and quantity; severe insect or disease damage.
Dead (D): dead tree, leaves absent; twigs brittle.

Appendix C - Significant Vegetation Criteria from *LOCAL LAW NO. 6 PROTECTION OF VEGETATION, SUMMARY OF PROVISIONS*, (Redland Shire Council 2003:4)

"significant vegetation" *means that the vegetation is*

a) a valuable part of the natural heritage of the area; or

b) an example of a rare or threatened species or a species that may be, or may be about to become, a rare or threatened species; or

c) a valuable scientific resource; or

d) a valuable source of propagating stock or of other horticultural value; or

e) of historic significance because of its association with an important historical event or the commemoration of an important historical event, whether of local, regional, state or national significance; or

f) of cultural significance because of its significance in Aboriginal rituals, religious observance or legend;

g) a valuable educational or recreational resource; or

h) a significant habitat for native animals (including native or migratory birds) or a part of a fauna and flora corridor; or

i) a significant part of a vegetation system or other ecological system; or

j) important for maintaining the life-supporting capacities of ecological systems for present and future generations; or

k) important for protecting a water catchment area; or

l) important for its support for natural or artificial landforms such as drainage lines, watercourses bodies of water, foreshores, slopes or unstable and erodible soils; or

m) important for its aesthetic value or its beneficial effect on the amenity of the locality in which it is situated; or *n) important for its age, height, trunk circumference, or canopy spread; or*

o) important for its unique contribution to the landscape; or

p) a visual buffer against unsightly objects or a buffer against pollutants, light spillage, noise or other factors that have an adverse effect on the environment; or

q) important as a buffer zone adjacent to areas of conservation significance; or

r) important in the context of the objectives of State or Local Government planning, land management and environmental management policies and initiatives; or

s) significant for such other reason as may be prescribed by local law policy.

Appendix D - Attributes of koala habitat trees and preferred feeding trees

	Attribute	Number	%
Height	< 4 m	29	23.57
	4 - 10 m	67	54.47
	>10 m	27	21.95
Dbh	< 10 cm	5	4.67
	10 - 20 cm	44	41.12
	20 - 50 cm	41	38.32
	50 - 100 cm	13	12.15
	> 100 cm	4	3.74
Health	Excellent	23	19.16
	Good	56	46.66
	Fair	37	30.83
	Poor	4	3.33
	Dead	0	0
Dieback	none	86	75.44
	minor	23	20.17
	major	5	4.38
	severe	0	0
Epicormic growth	Yes	5	4.032
Mistletoe	none	124	100
Canopy Loss	Yes	16	12.9
Koalas	present	0	0
Scratches	None	16	29.63
	Few	11	20.37
	Some	9	16.67
	Many	18	33.33
	TOTAL	54	100
Scats	Yes	18	14.52
Significant	Habitat	8	
	height, dbh, circ.	8	
	Aesthetics	4	
location	Private property	60	51.72
	Street Scape	44	37.93
	Open Space	12	10.34
Powerlines	no	85	73.27
	underneath	13	11.21
	next to	18	15.52

Appendix D Continued

Attributes of preferred koala food trees

		UR	MC	MDR	TOTAL	%
Height	< 4 m	0	3	8	11	39.28
	4 - 10 m	1	0	3	4	14.28
	>10 m	5	0	8	13	46.42
Dbh	< 10 cm	0	0	1	1	4.54
	10 - 20 cm	0	3	5	8	36.36
	20 - 50 cm	0	0	5	5	22.72
	50 - 100 cm	2	0	5	7	31.81
	> 100 cm	0	0	1	1	4.54
Health	Excellent	1	1	2	4	14.28
	Good	2	2	13	17	60.71
	Fair	3	0	3	6	21.42
	Poor	0	0	1	1	3.57
	Dead	0	0	0	0	0
Dieback	none	4	3	18	25	89.28
	minor	1	0	1	2	7.14
	major	0	0	0	0	0
	severe	0	0	0	0	0
Epicormic growth	Yes	0	0	0	0	0
Mistletoe	none	0	0	0	0	0
Canopy Loss	Yes	0	0	3	3	10.71
Koalas	Present	0	0	0	0	0
Scratches	None	0	0	**0**	0	0
	Few	1	0	**5**	6	21.4
	Some	0	0	**1**	1	3.57
	Many	0	0	**10**	10	35.71
Scats	Yes	0	0	8	8	28.57
Significant	Habitat	0	0	**3**	3	10.71
	height, dbh, circ.	0	0	**3**	3	10.71
	Aesthetics	0	0	**1**	1	3.57
Location	**Private property**	4	3	**2**	6	23.08
	Street	0	0	**11**	11	42.3
	Open Space	0	0	**6**	6	23.08
Powerlines	no	6	3	9	18	64.28
	underneath	0	0	2	2	7.14
	next to	0	0	8	8	28.57

Appendix E - Area contributions of land use planning zones for Redland City's Urban Footprint

Zoning		Area (m^2)	ha	%
Urban Residential	UR	30169956.5	3016.99	34.26
Conservation	C	13387521.1	1338.75	15.2
Open Space	OS	9550393.5	955.03	10.84
Medium Density Residential	MDR	9272457.5	927.24	10.53
Park Residential	PR	6889340.5	688.93	7.82
Community Purposes	CP	5425841.1	542.58	6.16
Emerging Urban Community	EUC	3539431.4	353.94	4.02
Low Density Residential	LDR	2926964.2	292.69	3.32
Environmental Protection	EP	2927056.3	292.7	3.32
Major Centre	MC	1597802.1	159.78	1.81
Commercial Industry	CI	1219532.1	121.95	1.38
General Industry	GI	565418.9	56.54	0.64
Marine Activity	MA	271720.4	27.17	0.3
Local Centre	LC	176210.8	17.62	0.2
Neighbourhood centre	NC	109064.3	10.90643	0.123880395
District Centre	DC	11176.2	1.11762	0.012694457
TOTAL		**88039886.9**	8803.98869	100

Appendix F – Non Tree and Non Koala Tree data spreadsheet

Grid ID		29499
Zone		MDR
Location		29 QUEEN ST
No. of dwellings		36
Ground Truth Data		
Non trees	shrubs	
	dead trees	
	removed trees	
	not visible	
	Other non tree	
Total Non-Trees		0

other non koala trees	Palms	Cocos		golden cane		Alexander		Cabbage		Other palms		Total Palms	0
	other non koala trees	*Acacia fimbriata*		*Callistemon V.*		lemon		silky oak				Total other non koala trees	0
		Acacia other		*Callistemon. S.*		Leopard		Silver wattle					
		African tulip		Camphor laurel		Leptospermum		Small leafed lilly pilly					
		Avocado		*Cassia fistula*		louguat		Soapy ash					
		Bamboo		Celtis		Lychee		Starfruit					
		Banana		*G.sumatrum*		Macadamia		*Szygium*					
		banksia		Christmas bush		Mango		Tree fern					
		Bauhinia		Feijoa		Mock Orange		Tuckeroo					
		Benhamin Fig		Fig		Mulberry		Tulipwood					
				Flame		Norfolk pine							
		black wattle		Frangipani		Pandanus		Umbrella					
		Blueberry ash		Ivory Curl		Paw paw		Unidentified					
		Broadleaf pepper		Jacaranda		Poincianna		White cedar					
				Kauri pine		Pride of india							
		TOTAL	0	TOTAL	0	TOTAL	0	TOTAL	0	TOTAL	0		
	Total non koala trees												0

Appendix G – Koala Habitat Tree data spreadsheet

Grid ID												
Zone												
Location												
Koala trees												
Number ID		1	2	3	4	5	6	7	8	9	10	11
Species												
Food Tree?	Preferred (3)											
	Other Primary (2)											
	Secondary (1)											
	Other habitat tree (0)											
Height	< 4 m (1)											
	4 - 10 m (2)											
	>10 m (3)											
Dbh	cm											
health	Excellent (E)											
	Good (G)											
	Fair (F)											
	Poor (P)											
	Dead (D)											
Dieback	none (0)											
	minor (1)											
	major (2)											
	severe (3)											
Epicormic growth	Y / N											
Mistletoe	none (0)											
	minor (1)											
	major (2)											
	severe (3)											
Canopy Loss	%											
Koalas	Y / N											
Scratches	None (0)											
	Few (1)											
	Some(2)											

	Many (3)												
Scats	Y / N												
	No												
	Habitat												
	height, dbh, circ.												
Significant	Aesthetics												
	Private property (PP)												
	Open Space (OS)												
location	Road Reserve (RR)												
Powerlines	Y/N												

Appendix H – Biodiversity of 19 hectares of the 25 Ground truth sample.

Common name	Scientific Name	Total abundance	Average / ha	%
Alexander Palm	***Archontophoenix alexandre***	**191**	**10.05**	**18**
Unidentified	**-**	**157**	**8.26**	**15**
Golden Cane Palm	***Dypsis Lutescens***	**122**	**6.42**	**12**
Koala habitat trees	***Corymbia, Eucalyptus, Lophostemon and Melaleuca***	**101**	**5.31**	**9**
Other Palms	**-**	**56**	**2.94**	**5**
Cocos Palm	***Syagrus romanzoffiana***	**48**	**2.52**	**5**
Poincianna	***Delonix regia***	**45**	**2.36**	**4**
Small Leafed Lilly Pilly	***Syzigium luehmanni***	**42**	**2.21**	**4**
Weeping Bottlebrush	***Callistemon viminalis***	**28**	**1.47**	**3**
Leopard Tree	***Caesalpinia ferrea***	**25**	**1.31**	**2**
Mango	***Mangifera sp.***	**19**	**1**	**2**
Silky oak	***Grevillea robusta***	**17**	**0.89**	**2**
Tulipwood	***Harpullia pendula***	**16**	**0.84**	**2**
Jacaranda	***Jacaranda mimosifolia***	**14**	**0.73**	**1**
Umbrella Tree	***Schefflera actinophylla***	**12**	**0.63**	**1**
Frangipani	***Plumeria rubra***	**11**	**0.57**	**1**
Tuckeroo	*Cupaniopsis anacardioides*	9	0.47	<1
Bamboo		8	0.42	<1
Blueberry Ash	*Elaeocarpus reticulatus*	7	0.36	<1
Paw Paw	*Asimina sp.*	7	0.36	<1
African Tulip Tree	*Spathodea campanulata*	6	0.31	<1
Orchid Tree	*Bauhinia variegate*	6	0.31	<1
Ivory Curl Flower	*Buckinghamia celsissima*	6	0.31	<1
Avocado	*Persea americana*	5	0.26	<1
Szygium	*Syzygium sp.*	5	0.26	<1
Banana	*Musa sp.*	4	0.21	<1
Beach Hibiscus	*Hibiscus tilieaceus*	4	0.21	<1
Black Wattle	*Acacia leiocalyx*	4	0.21	<1
Broadleaf Pepper	*Schinus terebinthifolius*	4	0.21	<1
White Bottlebrush	*Callistemon salignus*	4	0.21	<1
Golden Shower Tree	*Cassia fistula*	4	0.21	<1
Mulberry	*Morus nigra*	4	0.21	<1
Norfolk Pine	*Araucaria heterophylla*	4	0.21	<1
Crepe Myrtle	-	4	0.21	<1
Queensland Silver Wattle	*Acacia podalyriifolia*	4	0.21	<1
Tree fern	-	4	0.21	<1
Wattle	*Acacia sp.*	3	0.15	<1
Cabbage Tree Palm	*Livistona sp.*	3	0.15	<1
Camphor Laurel	*Cinnamomum camphora*	3	0.15	<1
Lemon	-	3	0.15	<1
Mock Orange	-	3	0.15	<1
White Cedar	*Melia azederach*	3	0.15	<1
Brisbane Golden Wattle	*Acacia fimbriata*	2	0.1	<1
Banksia	*Banksia sp.*	2	0.1	<1

Benhamin Fig	*Ficus benjamina*	2	0.1	<1
Feijoa Tree	*Feijoa sellowiana*	2	0.1	<1
Flame Tree	*Brachychiton Acerifolius*	2	0.1	<1
Louquat	*Eriobotrya japonica*	2	0.1	<1
Macadamia	*Macadamia integrifolia*	2	0.1	<1
Pandanus	*Pandanus sp.*	2	0.1	<1
Casuarina	*Casuarina sp.*	1	0.05	<1
Chinese Elm	*Celtis sinensis*	1	0.05	<1
Cheese tree	*Glochidion sumatrum*	1	0.05	<1
New Zealand Christmas Bush	-	1	0.05	<1
Queensland Kauri Pine	*Agathis robusta*	1	0.05	<1
Tea Tree	*Leptospermum sp.*	1	0.05	<1
Lychee	*Litchi chinensis*	1	0.05	<1
Soapy ash	*Alphitonia excelsa*	1	0.05	<1
Starfruit	*Averrhoa carambola*	1	0.05	<1
TOTAL		1050	55.26	100