Koala Habitat and Population Assessment for Gold Coast City LGA

Final Report to Gold Coast City Council

July 2007

biolink pty ltd
ecological consultants

PO Box 196 Uki NSW 2484
Tel 02 6672 6966
Fax 02 6672 6077
www.biolink.com.au

Koala Habitat and Population Assessment for the City of the Gold Coast

Final Report to Gold Coast City Council

July 2007

Part 1

Introduction

EXECUTIVE SUMMARY

The Gold Coast City LGA (GCCLGA) covers an area of approximately 1,453 square kilometres within the South East Queensland Bioregion, extending from Rainbow Bay in the north to the New South Wales border in the south and Beaudesert Shire in the west. This report describes the results of a shire-wide koala habitat and population assessment undertaken on behalf of Gold Coast City Council, a project guided by both the South East Queensland Regional Plan (SEQRP) and the *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016* (the KCP).

Detailed koala population assessments in the Coombabah and Coomera-Pimpama Koala Habitat Areas (CKHA and C-PKHA respectively) involved a systematic sampling strategy to delineate metapopulation boundaries, provide estimates of koala density/population size, compile data on koala population demographics and disease status and to examine issues of population viability. Collectively, 315 field sites were sampled. Koalas were abundant and widespread in both KHAs, with density estimates of between 0.22 and 0.23 koalas/hectare on average. A comparison of Spot Assessment Technique (SAT) *vs* Strip-transect methodologies to derive koala density estimates revealed that while the former approach resulted in a smaller variance, outcomes from both do not differ significantly. Extrapolation of koala density data over the area of available habitat resulted in population size estimates of 160 koalas in the CKHA and 510 koalas within the C-PKHA. Combined data from 39 randomly captured koalas from both areas revealed an approximately normal distribution of age classes, high levels of reproductive output and little evidence of clinical expression of disease. Population Viability Analysis of the CKHA revealed a likely need for active population management in order to afford this population a measure of long-term viability.

Data from 7,842 trees collected during surveys in the CKHA and C-PKHAs was augmented by additional field survey work throughout the remainder of the GCCLGA in order to more broadly examine the distribution, quality and

use of habitat by koalas. To this end a combination of SAT and strip-transect methodology was again applied for the purposes of sampling Regional Ecosystems that contained eucalypts, along with development of a Rapid Assessment Protocol (RAP) that targeted several *Eucalyptus* spp with localised and/or restricted distributions within the GCCLGA. These field surveys involved 44 primary sites and 26 RAP sites sampling a total of 3,045 trees from 21 Regional Ecosystems. Evidence of habitat use by koalas was recorded in 18 of the 44 primary sites to provide an estimated *Area of Occupancy* of approximately 41%, while estimates of koala density ranged from 0.09 – 0.11 koalas/hectare. Extrapolation of these estimates across the total area of REs containing eucalypts yielded a population estimate of 4,316 – 5,131 koalas for the GCCLGA.

A total of 11,190 trees from over 9 Families and more than 19 Genera constituted our tree use data set, including at least 26 species from the Genus *Eucalyptus*. Redefining Eucalyptus to include the Genera *Corymbia*, *Angophora* and *Lophostemon* for the purposes of data analysis, four tree species – Forest Red Gum *E. tereticornis*, Tallowwood *E. microcorys*, Grey Gums *E. propinqua/E. biturbinata* and Swamp Mahogany *E. robusta* were identified as the most preferred koala food tree species (PKFTs) within the GCCLGA, with levels of use that did not differ significantly when compared across the range of REs within which they occurred. Data on the proportional abundance of preferred koala food trees within the 74 REs in which they occurred allowed us to implement a 5–tiered hierarchical koala habitat classification which resulted in approximately 47,605 ha of potential koala habitat being identified within the GCCLGA.

Analyses of 657 historical records for the period 1927 – 2005 revealed that koalas were once more widespread throughout the GCCLGA than they are today. While the species remains widespread, the records suggest that there has been a reduction of at least 14% in the historical range parameter *Extent of Occurrence*, along with a significant reduction throughout the GCCLGA of at least 10% in the associated *Area of Occupancy,* the greater part of which has occurred east of the Pacific Motorway. Over 300 historical koala records were associated with Version 5 Regional Ecosystem mapping. Analysis of these records revealed a primary association with REs that were dominated by eucalypts, along with a trend towards a greater number of records to be associated with an increase in the area of aggregated RE forest cover. When corrected for aggregated area, koala records were 5 times more likely to occur in REs that contained PKFTs. Evidence for generational persistence was also widespread throughout the GCCLGA, with at least 6 source localities identified wherein koalas have been consistently recorded over periods of time that span at least 3 - 5 consecutive decades.

Identification of new KHAs involved a six-stepped approach largely informed by key outcomes from our study. The process firstly involved a filtering of potential koala habitat through a RE-based habitat assessment matrix, along with identification of likely GCCLGA koala management "precincts" based on what were perceived as primary barriers to recruitment and dispersal, notably the Pacific Motorway, Gold Coast Highway and all major watercourses. Secondly was a requirement for a aggregated potential koala habitat requirement of at least 1,500ha - nominally in the form of one or more large and/or interconnected bushland patches - this being the minimum area required to sustain at least the Minimum Viable Population of ~170 koalas while also allowing for a minimum occupancy rate of approximately 50% in order to accommodate meta-population expansion and/or contraction. To this was added a requirement for evidence of generational persistence. Areas so identified were then overlain with the SEQRP's urban footprint in order to identify Koala Sustainability and Urban Koala Areas. This approach resulted in identification of 5 new KHAs west of the Pacific Motorway. Elsewhere we have proposed one further KHA, a small area of 925 ha primarily composed of KSA and UKA that is an attempt to save the Burleigh koalas from what otherwise looks like certain localised extinction.

The GCCLGA has a large and topographically diverse hinterland that supports extensive areas of *Eucalyptus* dominated forest and/or Woodland, much of which contains PKFTs. Indeed, the very nature of much of this terrain appears to have played a major role in ensuring that koalas remain widespread and relatively abundant in this area. The obvious question that arises is whether (or not) koalas have a secure future within the GCCLGA, to which our qualified response would be in the affirmative. Having said this, we remain mindful that about 15% of the GCCLGA's koala population is effectively isolated in three sub-populations east of the Pacific Motorway, none of which have a guaranteed future. The remaining 85% survives in an increasingly fragmented habitat matrix bisected by road and water barriers, each precinct with differing levels of threatening processes that range from development pressure at the urban/bushland interface, road strike, ongoing habitat loss and increases in fire frequency and intensity. In short, there are no grounds for complacency and it will only be by effectively managing each of the parts that the whole will be preserved. In order to further assist this process, our report concludes with a discussion of existing Koala Conservation Criteria and provides a series of recommendations intended to both assist future planning and facilitate more sustainable development outcomes.

Introduction

Koala Ecology – a brief overview

The koala - Australia's largest arboreal marsupial - is an obligate folivore that feeds primarily on trees of the genus *Eucalyptus*. The distribution of koalas in eastern Australia extends from far north-eastern Queensland to the Eyre Peninsula in South Australia (Strahan 1995). Throughout this range, koalas have been reported as utilising a diverse range of *Eucalyptus* species (Hawkes 1978; Lee and Martin 1988; Hindell and Lee 1990; Phillips 1990; White and Kunst 1990; Melzer and Lamb 1996; Lunney *et al.* 1998). However, within a given area only a few of the available *Eucalyptus* species will be preferentially browsed, while others, including some non-eucalypts, may be incorporated into the diet as supplementary browse and/or utilised for other purposes (Lee and Martin 1988; Hindell and Lee 1990; Phillips 1990; Phillips 1999; Phillips *et al.* 2000, Phillips and Callaghan 2000).

Koalas are not a highly fecund species; females reach sexual maturity between eighteen months to two years of age and can theoretically produce one offspring each year. Observations however, indicate that on average most females in wild populations breed every second year over the term of their reproductive lives (McLean and Handasyde 2006). The longevity of individuals in the wild also varies but probably averages 8 – 10 years for most mainland populations, with Phillips (2000) estimating a generation time for koalas of 6.02 ± 1.93 (SD) years.

While the socio-biology of koalas is a critical aspect of their management, it remains something that is generally overlooked and/or ignored in the majority of planning studies. Factors that influence the distribution of koalas at the population level are more complex than that simply represented by habitat considerations alone. Studies of free-ranging koalas have established that those in a stable breeding aggregation arrange themselves in a matrix of overlapping home range areas (Lee and Martin 1988; Faulks 1990; Mitchell 1990). Home range areas vary in size depending upon the quality of the habitat (measurable in terms of the abundance of preferentially utilised food tree species) and the sex of the animal (males tend to have larger home range areas than females). Moreover, long-term fidelity to the home range area is generally maintained by adult koalas in a stable population (Mitchell 1990; Phillips 1999) and dissolution of such social structure has been identified as a contributing factor to population decline in some areas (Phillips 2000a). Hence the concept of compensating for actions that have the potential to degrade koala habitat by either moving affected animals or providing alternative habitat elsewhere is delusive; maintenance of existing social structure should be a primary consideration in terms of developing conservation and management strategies for free-ranging koala populations.

Recent research by McAlpine *et al.* (2005; 2006; 2007) into the landscape ecology requirements of koalas in the Noosa Shire indicated that the chance of koalas being present declined rapidly as the percentage of koala habitat or overall forest cover fell below 60-70% of the landscape. There was also evidence of critical patch size requirements for koalas, with koalas more likely to be absent from patches of primary and secondary habitat that were < 50 ha in size, while the chance of koala presence started to decline below a habitat patch size of around 150 ha.

Threatening processes

Free-ranging koala populations are threatened by a variety of processes:

- Destruction of koala habitat by ill-advised clearing for urban development, roadwork, agricultural and mining activities.
- Fragmentation of koala habitat such that barriers to movement are created that isolate individuals and populations, hence altering population dynamics, impeding gene flow and the ability to maintain effective recruitment levels.
- Unsustainable mortalities caused by dog attacks and road fatalities.
- Mortalities caused by stochastic events such as fire (including high fire frequency for the purposes of fuel reduction).
- Degradation of habitat by logging of preferred food trees.

The majority of these processes occur in the Gold Coast City LGA, particularly in the coastal lowlands.

Conservation and legislative context

The conservation status of koalas varies across Australia, from supposedly secure in some areas to vulnerable, rare or extinct in others (ANZECC 1998). In 2004, Koalas were listed as a Vulnerable[#] species throughout the South East Queensland (SEQ) Bioregion for purposes of the *Nature Conservation Act 1992*. Given this circumstance, sustainable planning for koalas should endeavour to minimise the potential for adverse impacts in known koala habitat, ensuring that adequate areas of suitable habitat and linkages to assist ongoing processes of recruitment and dispersal, are maintained or restored.

The *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016* (hereafter referred to as the KCP) came into effect in October, 2006. The KCP seeks to halt the decline in koala numbers and to provide for koala population recovery. To assist this objective the KCP divides Queensland into three Districts (A – C) based on the perceived level of threat to koalas. District A covers 18 local government areas in SEQ, including Gold Coast City, where threats associated with habitat destruction and other human impacts were considered greatest. Within these areas, the KCP proposes to achieve its underlying conservation objectives through delineation of cadastrally defined *Koala Habitat Areas* (KHAs), these being nominally comprised of *Koala Conservation*, *Koala Sustainability* and *Urban Koala Areas*, two of which have already been delineated within the GCCLGA. However the status and distribution of koalas elsewhere in the GCCLGA has not been addressed. Appropriately, the KCP encourages Councils to undertake further assessment and mapping in order to identify additional areas and to refine the mapping within existing KHAs.

Further underpinning the KCP is a key aim of minimising impacts from development and land use within identified KHAs in the SEQ region. The KCP

[#] as defined by the *Nature Conservation Act 1992*.

contains a set of Koala Conservation Criteria for assessable development in KHAs that are called up by the Koala Conservation Policy within the South East Queensland Regional Plan (SEQRP). These criteria seek to ensure that the needs of koalas are taken into consideration through measures such as minimising development footprints and habitat loss, making provision for koala movement, avoiding increases in evening traffic, incorporating vegetated habitat links and rehabilitation programs, and minimising impacts during construction activities. While this is a commendable and long overdue initiative, the KCP is limited in restricting the classification of any koala habitat that overlaps with the SEQRP's Urban Footprint to either "*Koala Sustainability*" or "*Urban Koala*" Areas (as opposed to *Koala Conservation Area*). In the case of *Urban Koala Areas*, the Koala Conservation Criteria are constrained to "where applicable" application of measures such as maintaining koala habitat linkages and incorporating koala sensitive development. While no doubt an attempt at providing planning certainty, this approach has the potential to create challenges in some areas where high quality koala habitat and the presence of significant koala populations offer the potential for conflict with existing development visions and/or commitments. Other exceptions to key provisions of the KCP include extractive industry in Key Resource Areas identified in an approved State Planning Policy and community infrastructure where an overriding public need has been identified.

The Study Area

The GCCLGA covers 1,453 square kilometres within the South East Queensland Bioregion and extends from Rainbow Bay in the north to the New South Wales border in the south and Beaudesert Shire in the west. In June 2004, there were 469,214 residents living in Gold Coast City making it the sixth largest city in Australia. The population is expected to increase to 700,407 by the year 2021. With an elevation range from sea level to over 1000m above sea level, a diverse variety of vegetation communities and fauna habitats are represented in the GCCLGA including cool-temperate, sub-tropical and littoral rainforests, coastal heathlands and wetlands, along with extensive areas of eucalypt forests and woodlands. Recent 1: 25,000 (citywide) and 1:10,000 (wetland and riparian) vegetation and Regional Ecosystem mapping prepared by the Queensland Herbarium (Ryan *et al.* 2003) indicated that in 2001, 41% (56,158 ha) of the pre-clearing vegetation remained as remnant vegetation in the GCCLGA, with a further 5.4% (7,417 ha) classified as disturbed vegetation. A total of 76 remnant vegetation types and 11 non-remnant vegetation types have been mapped and described (Ryan *et al.* 2003). Common Nature Conservation Classification System mapping prepared for Council (Francis *et al.* 2005), identified 82% (55,860 ha) of the remaining native vegetation and habitat areas in the Shire as having State Significance for biodiversity. A further 6,495 ha (9%) was identified as Regionally Significant and 5,313 ha (8%) as being of Local Significance. The Gold Coast occupies one of the most biologically diverse areas in Australia. Vertebrate fauna recorded in the Shire include at least 34 species of amphibians, 71 species of reptiles, 25 fish species, 323 bird species and 72 mammal species (see www.goldcoastcity.com.au).

This report details the results of a project undertaken on behalf of Gold Coast City Council that has the primary aims of:

1. determining the distribution, abundance and status of koala populations across the GCCLGA,
2. undertaking detailed population and habitat assessments within identified *Koala Habitat Areas* as mapped by the *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016*, and
3. identifying and mapping koala habitat within the remainder of the GCCLGA in a manner consistent with that required by the *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016*.

Structure of this Report

Following this introduction, the koala habitat and population assessment that follows comprises four main parts – Part 2 details the results of a comprehensive habitat and population assessment of the two mapped *Koala Habitat Areas* at Coombabah and Coomera-Pimpama respectively. Part 3 takes data from Part 2 and builds on it to look at the remainder of the GCCLGA from a koala's perspective, this time with a focus on understanding the importance and distribution of Regional Ecosystems and their ability to support and/or sustain free-ranging koala populations. Part 4 then provides a detailed analysis of historical koala records for the GCCLGA, again building on the key outcomes from Parts 2 and 3. The last section (Part 5) is an integration of necessary statutory considerations and the key outcomes from Parts 2 – 4 in order to delineate and categorise new KHAs for the GCCLGA and latterly, propose additional guidelines that will hopefully assist longer-term planning processes in these areas.

Project Team

Project Manager/Principal Consultant…………………… Dr. Stephen Phillips

Ecologist ....Marama Hopkins

Conservation Biologist ....John Callaghan

GIS Specialist ....Dr. Jan Warnken

Technical/Field Assistants: ....Daen Audet, Marshall Chang, Calvin Gladman, Kerry MacMunn, Jan-Olaf Meynecke, Felicia Pereoglou and Dan Pollard.

Acknowledgements

We wish to commend Gold Coast City Council for initiating this study and remain indebted to a number of Council staff for their enthusiasm and support, including Andrew Cuttriss (Council's Project Manager), Warren Rowe, David Corkhill, Ned Wales, Gerri Briggs, Stephen Towner and others. Council Ranger Rodney Anderson unearthed relevant details of the Boonah to Binna-Burra koala translocations on our behalf. Queensland EPA (Deidre de Villiers) also provided input and early advice, while Scott Hetherington supplied us with PIT tags and a reader; Wildcare supplied the koala ear tags. Koala captures were undertaken in accord with Scientific Purposes Permit WISP03868306 and related approvals from Griffith University Animal Care and Ethics Committee.

Document Control

Draft #	Final	**Date**	**Signature**
Prepared by	M. Hopkins/S. Phillips/J. Callaghan	30th March 2007	
Reviewed by	M. Hopkins/S. Phillips/GCCC	25th July 2007	
Approved by	S. Phillips		

Acronyms used in this report

Acronyms are silly truncations used by lazy people and really have little place in the spoken form of the English language. Nonetheless, their use in a written document such as this can save both time and space. Below is a list of acronyms that have been used throughout this report, along with their associated and sometimes quite lengthy expansions. We have endeavored to precede our first use of a given acronym with its appropriate meaning but may have inadvertently omitted to do this in a few places along the way; this page is here in order to provide an easy reference point.

ANOVA: Analysis of Variance.
ANZECC: Australian and New Zealand Environment and Conservation Council.
AoO: Area of Occupancy.
CKHA: The Coombabah Koala Habitat Area.
C-PKHA: The Coomera – Pimpama Koala Habitat Area.
EoO: Extent of Occurrence.
EPA: The Environmental Protection Agency.
GCCLGA : Gold Coast City Local Government Area.
Ha: Hectares
IUCN: International Union for the Conservation of Nature.
KCA: a *Koala Conservation Area* (as defined by the KCP).
KCP: The *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006 – 2016.*
KHA: *Koala Habitat Area* (as defined by the KCP).
KSA: *Koala Sustainability Area* (as defined by the KCP).
KSDZ: Koala Sensitive Development Zone.
LGA: Local Government Area.
MCP: Minimum Convex Polygon.
MVP: Minimum Viable Population.
NKS: National Koala Survey.
OUM: Office of Urban Management.
PKFT: Preferred Koala Food Tree.
PKH: Potential Koala Habitat.
PVA: Population Viability Analysis.
QNPWS: Queensland National Parks and Wildlife Service.
RAP: Rapid Assessment Protocol.
RE: Regional Ecosystem.
SAT: the Spot Assessment Technique.
SEQ: South East Queensland.
SEQRP: the *South East Queensland Regional Plan.*
TWC: Tooth Wear Class.
UKA: *Urban Koala Area* (as defined by the KCP).

Part 2

The Coombabah and Coomera-Pimpama Koala Habitat Areas

Introduction

As outlined in Part 1, two *Koala Habitat Areas* (KHAs) have already been identified within the GCCLGA for purposes of the *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016* (the KCP), both of which lie in the northeast of the LGA; one at Coombabah (consisting mostly of what is now the Coombabah Lakelands Conservation Area), the other north of the Coomera River in the Coomera-Pimpama area.

We have systematically applied Spot Assessment Technique (SAT)-based sampling throughout many areas in eastern Australia because of its proven ability to provide detailed information about koala population size, metapopulation distribution and habitat use either at the landscape scale or within a localised area (eg. Biolink 2003, 2004, 2005a and 2005b; AKF 2004; Phillips *et al.* 2004)

The specific aims of this component of our study were

(i) to determine the extent and distribution of koala activity in the areas currently classified as KHAs,

(ii) to determine koala population size and density throughout both KHAs,

(iii) to assess the health and demographic status of both populations in order to provide an indication of their long-term viability and to make recommendations for their future management, and

(iv) to consider the need for amendments to the internal habitat classifications and boundaries of the two KHAs.

Methods

Study areas

Our study areas were essentially delineated by the boundaries of the two KHAs themselves; the Coombabah and Coomera-Pimpama KHAs (hereafter referred to as CKHA and C-PKHA), each comprising approximately 1,400ha and 3,640ha respectively (Figure 2.1).

Site selection

The vegetation mapping of Ryan *et al*. (2003) was utilised for the purposes of selecting areas of vegetation to survey for koala activity, filtered to remove those vegetation communities not containing eucalypts.

Site selection involved a systematic process in which the vegetation mapping for each KHA was overlain with a 250m x 250m grid in the CKHA and between the Pacific Motorway and the train line in the C-PKHA, and a 350m x 350m grid east of the train line in the C-PKHA, the latter rotated 45 degrees to improve coverage of the study area (Figure 2.2). Sampling sites were located where grid-line intersections fell within areas of native vegetation containing eucalypts. Universal Transverse Mercator (UTM) coordinates for these locations were programmed into a 12 parallel-channel Garmin GPS72 hand-held receiver navigating on a GDA94 datum. Additionally, 1:25,000 scale ortho-rectified aerial photography was inspected and sampling points intersecting small, unmapped patches of native vegetation and areas with scattered trees were also included for sampling.

Assessment of habitat use

Once located in the field, each point was sampled using the Spot Assessment Technique (SAT) of Phillips and Callaghan (Appendix I), modified to increase sampling efficiency by inferring application of a default *high use* activity level to a site as soon as ten trees scored positive for koala faecal pellets. Conversely, if the first 25 trees scored negative for faecal pellets, a default *low use* activity level was inferred.

Surveys at each SAT site also incorporated a search for koalas in every tree within a 25m radius of the centre tree (0.196ha) by three personnel. Opportunistic observations of koalas sighted during field assessments were also recorded.

Population assessment

Demographic attributes of koala populations within both KHAs were determined from a randomly captured sub-set of the population. Koalas were located opportunistically and through targeted searches. Two capture methods were employed depending on a given animal's location and ease of capture. In cases where the koala was deemed "catchable" it was encouraged to descend to the ground by waving a coloured flag attached to a telescopic pole above the animal's head whereupon it was captured at the tree base. In instances where capture using this method was deemed unlikely to succeed or to pose high risk to the koala or capture team, a custom-built koala 'trap' (Phillips submitted) was used.

Captured koalas were weighed prior to administration of a mild sedative (Alfaxan – CD RTU) (any back young were cradled in a small cloth bag or wrapped in soft material for the duration of the procedure and reunited with the mother just prior to release). Subsequent examination recorded the following:

a) sex,
b) population cohort – adult, s/adult or juvenile,
c) condition score - a subjective measure (scale of 1 – 10) based on the degree of muscle tissue development on the dorsal surface of both scapula,
d) reproductive status (females only) – presence/absence of back young or, where necessary, pouch examinations to establish presence of small pouch-young, recent evidence of lactation and/or pouch use,
e) disease status - presence/absence of clinical signs of Chlamydiosis (i.e. conjunctivitis or wet-bottom),
f) age - assigned on an incremental scale of tooth-wear class (TWC) using the criteria of Gordon (1991), and
g) general overall condition – a subjective three point scale of poor to excellent that incorporated attributes additional to the above (eg., colour of dorsal pelage, presence/absence of physical aberrations and/or other disease symptoms).

Ocular and urogenital swabs were also collected and a small punchlet biopsy obtained from the ear for subsequent genetic profiling and disease studies. Animals were tagged through the punchlet holes with individually numbered

Wildcare ear tags and microchipped (except in the case of females with back young). Once fully recovered from the sedative, animals were released at the base of the capture tree and monitored until they had ascended to a safe roosting height.

Data analysis

Koala 'activity' for each SAT site was obtained by dividing the number of trees which scored positive for koala faecal pellets by the total number of trees searched in that site. Koala activity levels for each SAT site were then used as a basis for GIS-based spatial analysis involving a combination of regularised splining and contouring to model koala activity patterns throughout the study area. This process produces a contour map delineating important "source" areas supporting resident koalas that, based on previous studies, invariably enclose the areas occupied by the majority of contemporary koala records and 100% of observed breeding females (Phillips unpub. data). For the purpose of identifying such areas within the two KHAs, we applied the threshold value of 22% based on the east coast medium - high population density activity model of Phillips and Callaghan (Appendix I).

Population estimate

For purposes of estimating koala abundance within each KHA, our 25m radial search at each SAT site intensively censuses an area of 0.196 ha. A density estimate was determined by dividing the number of koalas sighted in all SAT sites by the total area sampled by the radial searches. Because each site effectively represented a habitat 'block' of either 6.25 or 12.25 ha (derived from the 250m and 350m sampling grids), a population estimate could then be obtained by extrapolating the density estimate over the total habitat area (area of habitat block x no. of sampled SAT sites).

Population demographics & viability analysis

Demographic information obtained during population assessments of the CKHA and C-PKHA was used to provide an indication of each population's health, age-class structure and reproductive output. Population Viability Analysis (PVA) was carried out using the software package Vortex 9.60 (Lacy *et al*. 2006). Data for baseline assumptions was obtained directly from results of population assessments during this study or, if unavailable, was taken from current literature on koala studies that had used this technique (Penn *et al*. 2000; Lunney *et al*. 2002; Phillips 2002; Biolink 2005). Baseline scenario settings and their sources are provided in Appendix III. Scenarios were run over a 50-year timeframe using 1,000 iterations.

A 30% probability of fire was modelled for the CKHA with a resultant 15% reduction in reproduction and survival of the koala population. This aimed to reflect the high frequency but presumed low severity of small fires that are regularly lit within the park. A one in 20-year fire with a severity of 25% (reduction in reproduction and survival) was modelled for C-PKHA.

Modelling incorporated a low rate of incidental harvest to reflect mortality due to dog attack and motor vehicle strike (an annual harvest rate of 2%) for both study areas to reflect the current situation; this figure was based on the relatively low density of roads that currently traverse both study areas. For comparison, the effect of harvesting six percent of the population size annually was also examined. EPA and QNPWS data from the Moggill Koala Hospital indicate that the rate of annual incidental harvest due to road mortality and dog attack in other developed areas of southeast Queensland approximates six percent of the estimated population (QPWS 2002; EPA/QPWS 2006). This rate of harvest is likely to be reached (if not exceeded) within C-PKHA as the effect of urbanisation on koala mortality increases over the next 10 years. Explanations and further detail on selection of these parameters are discussed in biolink (2006), along with exploration of additional scenarios based on likely effects of imminent development within this particular KHA.

A minimum viable population (MVP) for koalas has been calculated by Phillips (unpub. data) to be approximately 170 animals, based on a knowledge of koala population dynamics but otherwise determined using the formulae of Kimura and Crow (1963) and Lehmkuhl (1984). Outputs obtained from PVA are presented with reference to this parameter.

Results

A total of 2,718 trees from 115 SAT sites within the CKHA were assessed (see Table 2.1). In the larger C-PKHA, 5,124 trees from 200 SAT sites were assessed. As detailed in Table 2.1, these results confirm a widespread distribution of koalas within both KHAs.

Table 2.1. Summary of field effort undertaken during systematic sampling of KHAs.

	Coombabah KHA	Coomera-Pimpama KHA
SAT sites	115	200
Trees sampled	2,718	5,124
No. Active sites	88 (76.5%)	159 (79.5%)
No. High / med use sites	60 (52%)	105 (52%)
Area searched for koalas	22.5 ha	39.2 ha

Koala activity

Koala activity was widespread though not evenly distributed throughout the KHAs. Of the 115 SAT sites sampled within CKHA, 88 returned signs of koala activity (i.e. faecal pellets recorded beneath at least one tree within the site), indicating that 76.5% of the sampled area contained evidence of habitat use by koalas. A similar, though slightly higher, extent of activity was recorded within the C-PKHA, with 159 of the 200 SAT sites returning evidence of koala activity (79.5%). Fifty-two percent of sites in each KHA returned an activity level equal to or above the 22% activity threshold adopted by this study. Splining and associated contour mapping consequently identified three major 'source' cells of koala activity within CKHA and one large 'source' area in C-PKHA (Figures 2.3 & 2.4). These cells delineate the metapopulation boundaries where breeding activity takes place and within which medium to high density, resident koala populations occur. Our field observations strongly support this modelling, with the majority of our opportunistic koala sightings being recorded within these boundaries along with all sightings of breeding females, the locations of which are also indicated in Figures 2.3 and 2.4.

Population estimate

During field assessments, koalas were recorded within five of the 115 SAT-based radial searches in CKHA, while nine koalas were located within seven SAT sites in C-PKHA thus forming the basis of density estimates for each KHA respectively. The resulting overall density estimates for both KHAs were similar: 0.22 ± 0.04 (SE) koalas/ha for CKHA and 0.23 ± 0.03 (SE) koalas/ha for C-PKHA. Densities of koalas within the overall boundaries of the metapopulation models were estimated at 0.43 koalas/ha for CKHA and 0.30 koalas/ha for C-PKHA. The population size for CKHA was estimated to be approximately 160 koalas, while that of C-PKHA is estimated to be approximately 510 koalas (Table 2.2).

Table 2.2. Summary of results from SAT-based assessments of koala populations in CKHA and C-PKHA

	Coombabah KHA	Coomera-Pimpama KHA
Koalas recorded†	5	9
Density estimate	0.22 ± 0.04 (SE) koalas/ha	0.23 ± 0.03 (SE) koalas/ha
Population estimate	159 ± 54 (95%CI)	510 ± 129 (95%CI)
Area currently occupied*	411ha	1205ha

†within SAT-based radial searches

*by a resident breeding koala population

Comparison of SAT and strip-transect techniques for estimating koala density

As part of our field assessment, the SAT method employed in the CKHA was paired with a variation of the survey methodology of Dique *et al*. (2003) for comparison purposes. Twenty-metre wide strip transects were located between pairs of previously surveyed SAT sites in areas identified as high/medium use. Transects were either 250 or 350 metres in length and were searched for koalas by three observers.

As outlined above, the overall koala density estimate for the CKHA derived from the SAT approach was 0.43 ± 0.06 (SE) koalas/ha. The strip transect method produced thirteen koala records from 48 transects covering a total area of 28.5ha. In order to calculate koala density from these surveys based on equitable areas surveyed by the two techniques, 20 subsets of 18-21 randomly selected transects approximating an area of 11.8ha were selected and koala density calculated by dividing the number of koalas recorded by the area surveyed in each set of transects. The mean koala density for these samples was 0.43 koalas/ha with an average SE of 0.11.

SAT method	S/Transect method
60 SAT sites 11.8ha surveyed 5 koalas recorded **0.43 ± 0.06** (SE) koalas/ha	20 subsets 11.8ha (mean) 5 koalas (mean) **0.43 ± 0.11** (mean±SE) koalas/ha

When compared to the SAT estimate of koala density within high/medium use areas of 0.43 koalas/ha, these estimates do not differ significantly (t=-0.0079, 19_{df}, P<0.001), although the standard error associated with the transect technique was higher. Moreover, data on a number of parameters additional to koala density are obtained through application of the SAT methodology, thus enabling an analysis of koala habitat use whether or not actual koala sightings are made in the area.

Population demographics

Demographic data was obtained from 39 captured koalas (20 males and 19 females). Three skulls were also collected during fieldwork and tooth-wear classes from these were included in demographic data. Condition scores ranged from 4.5 – 9, with the overall condition of koala populations in CKHA and C-PKHA found to be good and with few animals exhibiting outward signs of disease. Demographic data did not differ significantly between populations (Mean TWC: t=0.49, 40_{df}, P=0.31; proportion of females reproducing: G = 6.89, 3_{df}, P=0.08; sex ratios: G = 0.45, 3_{df}, P=0.93) and thus was pooled to provide a dataset of sufficient size to effectively minimize variance and hence provide meaningful data for PVA modelling purposes.

Tooth-wear classes of captured animals ranged from 1 – 7 with a median of 5 and were approximately normally distributed (Kolmogorov-Smirnov test: D_{max}=0.117; P>0.1), suggesting that the age of the majority of animals in the population is 3 – 8 years (Table 2.3). The age class distribution of captured animals and skulls is given in Figure 2.5. A high level of annual reproductive success was observed, with ~63% (C-PKHA) and ~71% (CKHA) of females exhibiting evidence of breeding (either captured with back or pouch young or with evidence of recent pouch use).

Table 2.3 Summary of data for koalas captured at CKHA and C-PKHA

	CKHA		C-PKHA	
	F	M	F	M
Captures	10	9	9	11
Mean weight (kg)	5.7	7.7	5.4	6.7
Median TWC*	5		5	
Mean/median age class*	3 - 8		3 - 8	
Reproductive adult females	7 (71%)		5 (63%)	

* includes data from three skulls

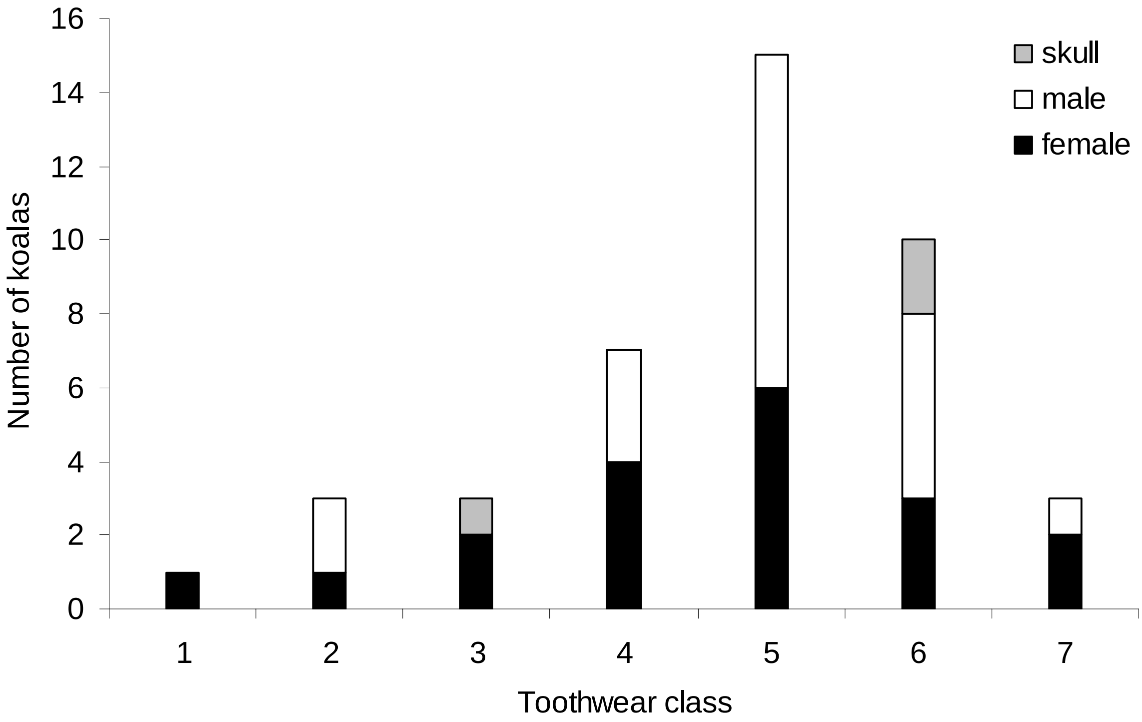

Figure 2.5. Age class distribution of captured koalas and three skulls in CKHA and C-PKHA.

Population Viability Analysis (PVA)

a) Coombabah KHA

PVA for the CKHA population indicated that despite its current size and otherwise good health, the population will likely decline to around half its current size within 20 years with a 39% probability of extinction within the next 50 years. Of the scenarios modelled, annual supplementation of the population with two or more females and one or more males, combined with maintenance of the existing carrying capacity and no increase in the level of threats, appears to be the minimum level of management required to maintain the population in the long term. These scenarios resulted in a zero probability of extinction over the next 50 years as well as stabilisation of the population size at between 120 and 140 animals. The modelled outcomes for each level of supplementation are presented in Figure 2.6.

This outcome is based on a number of assumptions however, such as the successful settlement of females in the area, their finding vacant habitat and then successfully reproducing. Additionally, a modelled increase in the severity and/or frequency of stochastic events resulted in the population being unable to sustain itself at numbers greater than half its current size. Therefore any increase in the level of this or other threatening processes is likely to result in an increase in the population's rate of decline.

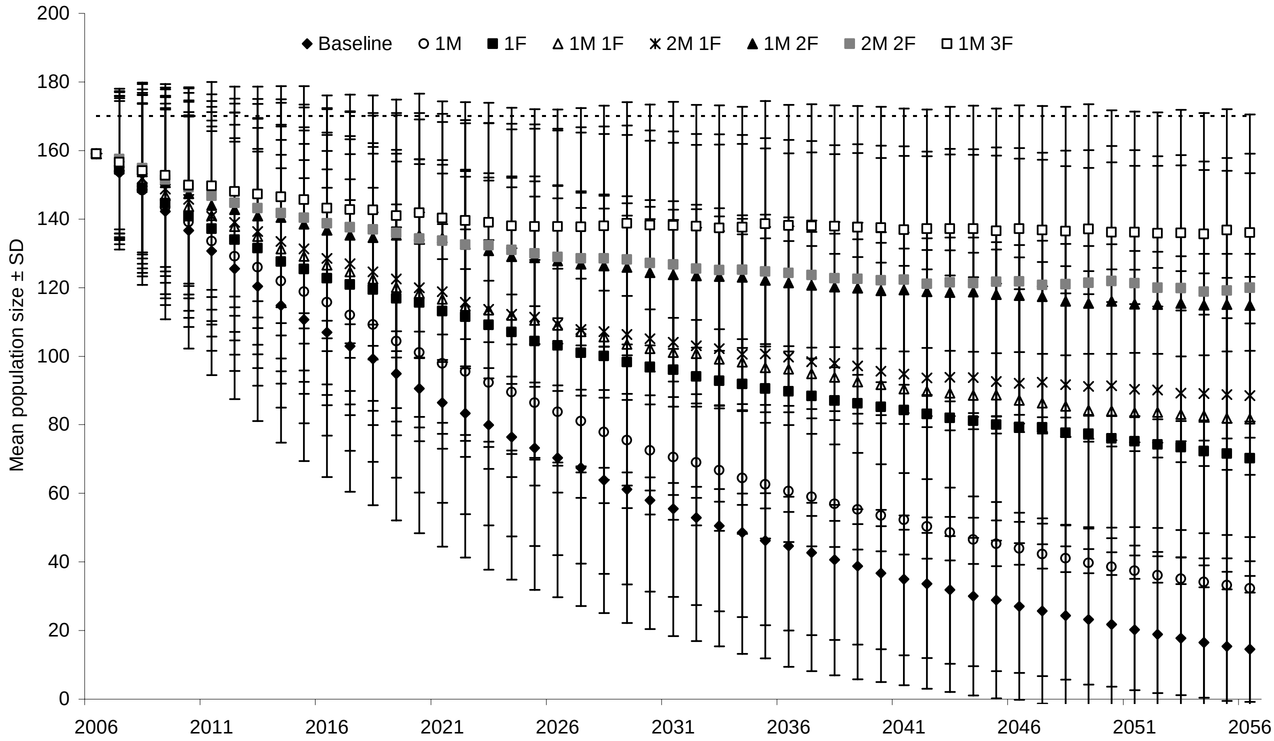

Figure 2.6. Mean koala population size ± SD for each year over 50 years at varying levels and combinations of supplementation for the Coombabah KHA. Dotted line indicates MVP of 170 animals.

b) Coomera-Pimpama KHA

Under current conditions PVA indicated that the C-PKHA koala population is in slow decline but likely to stabilise at approximately 400 animals over the next 50 years (Figure 2.7). The effect of increasing incidental harvest rates to 6% annually was an increase in the rate of decline of the population over the 50 year timeframe; population size fell from an initial size of 510 animals to below our estimated MVP of 170 animals within 50 years.

The future of the C-PKHA population has been discussed in some detail in a related report (Biolink 2006) which examines the likely consequences of envisaged short and long-term development outcomes and the commensurate increase in incidental harvest rates, along with the necessary management response to ensure long-term population viability.

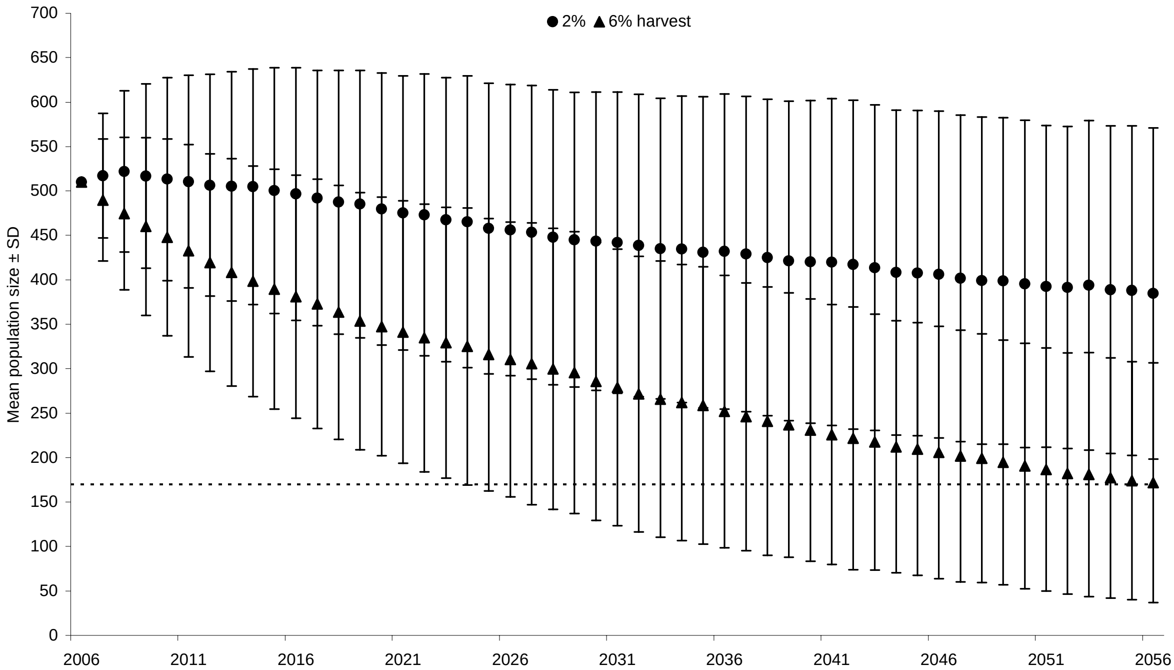

Figure 2.7. Mean koala population size ± SD for each year over 50 years at 2% and 6% annual harvest for C-PKHA. Dotted line indicates MVP of 170 animals.

Discussion

Within both KHAs, koala activity generally coincides with large areas of bushland but also includes cleared areas with scattered trees. This outcome demonstrates that the distribution of koala activity does not always correlate with the availability of highest quality koala habitat. In a management context, this is an important outcome as it highlights the important role of social factors in determining the distribution of free-ranging koala populations. Koala densities in the two KHAs are similarly high overall, with areas occupied by the resident population at this time comprising approximately 50% of the total area available. Other studies we have undertaken (Biolink 2003; 2004; 2005b) suggest that this occupancy rate is quite normal given that it effectively caters to the needs of koala metapopulation dynamics over time, such as expansion of high-occupancy cells into vacant areas of habitat and/or population extirpation in response to stochastic events such as fire.

Superficially, the future outlook for both populations should be positive, based on their overall health and reproductive success. However, this belies the underlying processes which threaten the long-term viability of each population and are perceptible only upon closer inspection and viability analysis. It is clear that koala populations, irrespective of their size, are poorly equipped to persist over the longer-term under the stresses associated with urban development.

The overriding factor in the predicted decline of the CKHA population is its currently small population size, which we estimate to be below the MVP. This renders the population vulnerable to processes which threaten small populations. Thus, the population is highly susceptible to stochastic events such as fire, and it is likely that an increase in fire frequency and/or severity would hasten the decline of this population. Additionally, opportunities for recruitment into the population are increasingly limited given the reserve's isolation in the surrounding urban landscape. It is likely that the persistence of the koala population in CKHA thus far is in part due to *ad-hoc* introductions of animals following their rescue from other parts of the GCCLGA and animals released into the reserve after periods in care. Two animals were captured during field assessments in the area with pre-existing ear-tags, thus supporting this assumption. Regardless, formal recording and monitoring of this activity, including documenting the number and frequency of introductions, would contribute to the future management of this population and should precede any future supplementation programs.

Despite its relatively large size, population viability analysis for C-PKHA has highlighted the inability of even a large koala population to persist under the pressure of habitat loss and increased harvest rates associated with future urban development. As alluded to earlier and in order to address the inevitable decline of this population as a result of imminent development pressure, a comprehensive management strategy has been formulated, details and discussion of which are presented in Biolink (2006).

Key outcomes

- Both CKHA and C-PKHA currently support high density koala populations where areas of significant koala activity cover approximately 50% of each KHA. The health status of both populations is generally good with few koalas showing outward signs of disease; female fertility is high and age class distributions are approximately normal, further evidence that both populations are currently in very good condition.

- Our population estimate of approximately 159 suggests that the number of koalas currently occupying CKHA is below the minimum required to ensure long-term population viability. PVA indicated that supplementation of the population on an ongoing basis will likely be required to ensure this population's persistence into the long-term. We recommend that a formal strategy for managing and monitoring this process should be developed by Council in consultation with the local koala rescuers and carers from Wildcare Australia.

- In contrast to the CKHA, the C-PKHA supports a biologically significant population of approximately 510 koalas. In its current state and under low harvest levels, the population is highly likely to persist over the long term. An increase in incidental harvest and a substantial reduction in available habitat, such as that associated with urban development planned for the area will severely diminish the population's probability of persistence.

- To allow for the persistence of koala populations within the two currently designated KHAs into the future, adequate resourcing and implementation of considered management strategies will be essential. Persistence of the CKHA population will require implementation of a supplementation program and maintenance of fire intensity at minimal levels. Rapid implementation of a comprehensive management strategy for C-PKHA is required if the impacts of pending development are to be successfully mitigated to allow koalas to persist in undeveloped areas.

Part 3

Koala Habitat within the GCCLGA

Introduction

Unfortunately, the KCP does not place emphasis on the importance of confirming the suite of locally-preferred koala food tree species in order to derive a map of koala habitat quality for a given LGA. Whilst the KCP allows for koala habitat quality mapping to be incorporated into the process of deriving a map of overall koala habitat areas, guidelines are only provided for survey methods intended to estimate koala abundance and density. In our opinion however, koala habitat quality mapping provides an essential basis for investigating the distribution and abundance of koalas, for conservation planning and for priority setting.

In order to define the quality of koala habitat it is essential to accurately determine koala food tree species preferences. It is widely recognised that koalas prefer a relatively small number of the *Eucalyptus* species in any given area (e.g. Hindell and Lee 1987; Ellis *et al*. 1999, 2002; Lunney *et al*. 1998, 2000; Martin and Handasyde 1999; Phillips *et al*. 2000; Phillips and Callaghan 2000; Smith 2004; Moore *et al*. 2004). The research necessary to identify koala food tree preferences requires stratification of field survey sites in order to adequately sample the range of vegetation communities containing eucalypt species and soil landscapes throughout the study area. For the purposes of this study, we used the EPA's Regional Ecosystem (RE) mapping. REs are defined as distinctive vegetation communities within a given bioregion that are consistently associated with a specific combination of geology, landforms and soils (Sattler and Williams 1999). Hence, for the purposes of this study we determined that the available RE mapping would serve as a suitable vegetation type/soil landscape facsimile for stratification purposes.

Our objectives for this component of the study were to:

(i) identify preferred koala food trees for the GCCLGA,

(ii) produce a map of ranked koala habitat quality, and

(iii) provide overall estimates of population size and Area of Occupancy within the GCCLGA.

Methods

Site selection

Vegetation cover for the GCCLGA was firstly stratified using Version 5 RE mapping (Ryan *et al* 2003). REs that did not contain eucalypts, along with all disturbed and non-remnant communities such as *Acacia* regrowth, *Allocasuarina* regrowth, camphor laurel, hoop pine, and plantations were excluded from sampling. RE types that had been sampled within the CKHA or the C-PKHA were also excluded from this process, with the aim of ensuring that we effectively sampled other potential koala habitat in addition to extending our sampling effort across the LGA. Primary site selection was based on a minimum "habitat sampling unit" of 15ha, this being the minimum area within which our proposed field survey methodology could be applied (see below). A 150m buffer was also applied in order to minimise to the maximum extent possible any likelihood of data being influenced by ecotonal effects and/or koala habitat use associated with adjoining but otherwise different REs.

The preceding process excluded many small, narrow or linear RE polygons from the process of site selection. Using GIS, centroid determination was then applied to the RE polygons so identified, the coordinates of which provided the location of our proposed survey sites. A minimum of 4 survey sites were then randomly selected for each RE in order to provide for replication and to maximise the dispersal of sites across the GCCLGA. Backup sites were also selected for each RE as replacements for primary sites that upon survey were found to lack koala faecal pellet evidence. UTM coordinates for each of the selected survey sites were programmed into a 12 parallel-channel Garmin GPS 72 hand-held receiver navigating on a GDA94 datum to assist location in the field.

Field survey

Once located in the field, the site was sampled using the Spot Assessment Technique (SAT) of Phillips and Callaghan (Appendix I). If no evidence of koala activity (i.e. koala faecal pellets) was recorded, then the single SAT site served as a point sample of the vegetation within the RE in question. If koala faecal pellets were recorded, then two additional SAT surveys and associated 25m radial searches were undertaken, each set at a distance of 100m from the central site along a pre-determined transect-line aligned either perpendicular to or along the contour in order to remain entirely within the RE being sampled. All assessments were supported by a strip-transect searches. These transects (*sensu* Dique *et al.* 2003) generally covered a minimum distance of 200m and involved three observers walking between 10 and 30m apart (depending upon visibility and terrain) covering a width ranging from 30 to 60m. Koala density estimates derived from each method were obtained by dividing the number of koala sightings by the total area searched.

Toward the latter part of the survey we determined the need for a Rapid Assessment Protocol (RAP) to sample some tree species not otherwise adequately represented in our tree use data set, but which have been reported as possibly being important to koalas, specifically the “boxes” *E. melliodora* and *E. moluccana* (Phillips 2000b). We also chose to include the ironbark *E. dura* in these surveys which, in common with the aforementioned species, has a restricted distribution within the GCCLGA. RAP surveys at these sites were generally undertaken in accord with the SAT methodology but confined to the target species plus any other trees already indicated by our data as likely to be amongst the suite of preferred koala food trees for the GCCLGA.

GPS coordinates were recorded for all koala sightings throughout the course of field work.

Data Analysis

Identification of preferred koala food trees (PKFTs)

For the purposes of identifying PKFTs across the GCCLGA, tree use data from our work within the CKHA and C-PKHA was included. Only species from the Genera *Eucalyptus*, *Corymbia, Lophostemon* and *Angophora* were included in this analysis and only if the species had been recorded from at least 10 independent sites with a pooled sample size of $n \geq 30$ trees. Hence, the data set captured those tree species from these four Genera that were most abundant and therefore likely to be of greatest potential importance in sustaining the local koala population.

Data for each tree species was pooled to obtain a proportional index of utilisation "*P*" referred to as the 'strike rate' (i.e. the proportion of surveyed trees of a given species with pellets). The mean site-based strike rates for those species considered to be taxonomically and/or ecologically similar were compared with a two-sample *t*-test. Data for pairs of species found to have strike rates that did not differ significantly were then pooled prior to further analysis. Pink Bloodwood *Corymbia intermedia* and Red Bloodwood *C. gummifera* data sets were pooled for analysis purposes given occasional difficulties with distinguishing between the species in the field.

Strike rates for the resulting species and/or species groups were analysed for significant heterogeneity using a single-factor ANOVA. Identification of the most preferred species was achieved by applying the SS-STP method for unplanned multiple comparisons using BiomStat V3.2 statistical software (Applied Biostatistics 1996) to examine all possible comparisons and to delineate non-significant subsets. The group of species in the first non-overlapping subset was considered to contain the PKFTs, and thus those of greatest ecological importance to koalas.

Variation in use of PKFTs between REs

Strike rates for PKFTs were also analysed for variation in use between REs. For this purpose, data for each species were firstly aggregated by RE and allocated to parametric, nonparametric or distribution-free data sets on the basis of criteria outlined in Table 3.1.

Table 3.1. Criteria for allocation of data for REs to each data set prior to analysis; where *n* = sample size for tree species "*i*"; and *P* = strike rate for tree species "*i*".

Parametric	Non-parametric	Distribution-free
number of sites ≥10	number of sites ≥3	number of sites >1
$n \geq 30$	$n \geq 10$	$n \geq 5$
$n_iP_i \geq 15$ and $n_i(1-P_i) \geq 15$	n_iP_i and $n_i(1-P_i) \geq 5$	n_iP_i or $n_i(1-P_i) \geq 5$

Parametric data sets were analysed for significant differences in mean strike rate of each PKFT between REs using either a single-factor ANOVA or two-sample t-test whereas Kruskal-Wallis ANOVA was applied to non-parametric data sets.

Koala Habitat Classification

Our approach to the matter of habitat classification involved assigning habitat quality classes for each RE based on the estimated proportional abundance (percentage) of PKFTs. Data from RAP sites were excluded from this analysis due to their being focussed on sampling a particular species and therefore generally not representative of their associated RE. Abundance categories were determined by examining the frequency distribution of average PKFT abundance within REs as recorded during field surveys in order to identify natural breaks in the data. Habitat quality categories A to E were underpinned by the definitions outlined below:

A. Primary Koala Habitat – REs wherein PKFTs are dominant or com-dominant.

B. Secondary Koala Habitat – REs wherein PKFTs are sub-dominant.

C. Tertiary Koala Habitat – REs wherein PKFTs are uncommon and/or rare.

D. Supplementary Koala Habitat - Eucalypt forest and/or woodland REs wherein PKFTs are absent.

E. Other Vegetation - REs not containing eucalypts.

The following set of decision rules was formulated in order to guide the process of assigning habitat quality classes. This was necessary for several reasons: a number of Version 5 RE polygons were described as composites; some RE descriptions were supported by limited field survey data; and some REs were excluded from our surveys due to their limited extent, high degree of fragmentation and/or small patch size.

Koala Habitat Classification decision rules:

1. In the case of composite REs, the habitat quality class was assigned on the basis of the dominant RE, even if the dominant RE lacked eucalypts.

2. Where our field data was limited to ≤2 independent sites, it was compared to the RE descriptions of Ryan *et al.* (2003). If the field data and the descriptions were consistent, then our data was used to classify the habitat quality for the RE. If the information from the two sources was discordant, the RE was classified as category Uw (Unknown - warranting further investigation).

3. Where our field survey site selection methodology excluded a given RE from sampling, estimated density of PKFTs was inferred from vegetation community descriptions in Ryan *et al.* (2003) and the RE descriptions available on the EPA website (2007). If a PKFT species (or a combination of PKFT species) was indicated to be either dominant or co-dominant within a community, the highest habitat quality category (A) was assigned. Where there was agreement on the absence of PKFTs from an RE, category D was assigned. Where RE descriptions listed a PKFT as present, but not as dominant, co-dominant or subdominant, the RE was assigned to category Uw.

4. Where the Ryan *et al.* (2003) descriptions were based on <2 detailed sites and conflicted with dominance information

currently reported on the EPA website, the RE was assigned to category Uw.

Results

Field Surveys

Tree use data from our survey work in the CKHA and C-PKHA collectively provided data on 7,842 trees comprising at least 18 species of *Eucalyptus*. Field surveys for the remainder of the GCCLGA involved 44 primary sites and 26 rapid assessment sites sampling a total of 3,348 trees including 23 species of *Eucalyptus*. The distribution of field sites throughout the GCCLGA is shown in Figure 3.1. Collectively, 11,190 trees including at least 26 *Eucalyptus* spp. and a wide range of associated non-eucalypt species were sampled across 32 mapped Regional Ecosystems (Tables 3.2 and 3.3). This is an unprecedented level of survey effort for a single LGA.

Amongst the eucalypts detailed in Table 3.3 are a number of taxonomically and/or ecologically similar species. Comparison of strike rates for these species returned no significant differences (Table 3.4), hence datasets for the following *Eucalyptus* species were pooled for subsequent analysis; *E. acmenoides*/*E. carnea*, *E. biturbinata*/*E. propinqua*, *E. crebra*/*E. siderophloia*, and *E. eugenioides*/*E. tindaliae*.

Table 3.2. Distribution of field effort within each RE sampled within the GCCLGA, indicating REs in which koala activity (faecal pellets and/or koala sightings) was recorded.

RE	SAT sites	Activity
12.1.1	22	Y
12.11.18	2	N
12.11.2	9	N
12.11.23	16	Y
12.11.3	10	N
12.11.3a	7	Y
12.11.5	20	Y
12.11.5a	1	Y
12.11.5a/12.11.5k	12	Y
12.11.5a/12.11.5j	87	Y
12.11.5j	8	Y
12.11.5k	22	Y
12.12.15	2	N
12.2.5	16	Y
12.2.5/14	2	N
12.2.7	5	Y
12.2.9	9	Y
12.3.11	21	Y
12.3.3	3	Y
12.3.5	13	Y
12.3.5a	13	Y
12.3.6	45	Y
12.8.1	4	N
12.8.14	15	Y
12.8.16	3	Y
12.8.19	1	N
12.8.20	1	N
12.8.8	4	Y
12.8.8a	3	Y
12.8.9	3	Y
12.9-10.7a	1	N
acac	3	Y

Table 3.3. Summary of eucalypt species sampled from the GCCLGA. Number of trees sampled, SAT sites and overall strike rate ± SE are reported.

Eucalyptus	*n*	No. Sites	Strike Rate	Non-*Eucalyptus*	*n*	No. Sites	Strike Rate
Primary dataset							
E. tereticornis	850	174	0.48 ± 0.02	*Lophostemon suaveolens*	551	146	0.24 ± 0.02
E. microcorys	438	95	0.49 ± 0.02	*Corymbia intermedia*^	1403	268	0.23 ± 0.01
E. biturbinata	20	5	0.75 ± 0.10	*L. confertus*	605	122	0.18 ± 0.02
E. propinqua	298	85	0.46 ± 0.03	*Angophora leiocarpa*	172	70	0.23 ± 0.03
E. robusta	87	12	0.36 ± 0.05				
E. resinifera	98	36	0.32 ± 0.05				
E. dura	99	13	0.31 ± 0.05				
E. acmenoides	73	28	0.21 ± 0.05				
E. carnea	405	117	0.29 ± 0.02				
E. crebra	326	76	0.28 ± 0.02				
E. siderophloia	700	172	0.30 ± 0.02				
E. seeana	150	62	0.27 ± 0.04				
E. eugenioides	100	33	0.19 ± 0.04				
E. tindaliae	161	47	0.22 ± 0.03				
E. fibrosa	110	18	0.22 ± 0.04				
Supplementary dataset							
E. pilularis	83	19	0.08 ± 0.03	*C. citriodora*	264	56	0.12 ± 0.02
E. grandis	53	12	0.02 ± 0.02	*C. tessellaris*	38	20	0.32 ± 0.08
E. moluccana	41	5	0.00 ± 0.00	*A. subvelutina*	34	6	0.15 ± 0.06
E. saligna	25	9	0.16 ± 0.07	*A. woodsiana*	18	7	0.44 ± 0.12
E. andrewsii	22	4	0.00 ± 0.00	*A. floribunda*	11	9	0.27 ± 0.13
E. approximans	11	1	0.00 ± 0.00	*C. henryi*	6	3	0.50 ± 0.20
E. melliodora	9	6	0.22 ± 0.14	*C. torelliana*	1	1	0.00 ± 0.00
E. patentinervis#	8	2	0.13 ± 0.12	Other spp.	3906	607	0.16 ± 0.01
E. globoidea	6	2	0.33 ± 0.19				
E. racemosa	5	2	0.20 ± 0.18				
E. spp	2	1	0.00 ± 0.00				
E. bancroftii	1	1	1.00 ± 0.00				
Totals	4181				7009		

hybrid of *E. tereticornis* and *E. robusta*, ^ includes *C. gummifera*, “Other spp” category includes species from the Genera *Melaleuca*, *Casuarina*, *Allocasuarina*, *Acacia*, *Pinus* and a number of rainforest species.

Table 3.4. Results of two-sample t-tests comparing strike rates for taxonomically or ecologically similar eucalypt species. *Eacm=Eucalyptus acmenoides*, *Ecar=E. carnea*, *Ebit=E. biturbinata*, *Epro=E. propinqua*, *Ecre= E. crebra*, *Esid=E. siderophloia*, *Eeug=E. eugenioides*, *Etin=E. tindaliae*

	Spp 1		**Spp 2**				
	mean	***n***	**mean**	***n***	***t***	***df***	**P(α=0.05)**
Eacm/Ecar	0.23	28	0.33	117	-1.24	143	0.21
Ebit/Epro	0.60	5	0.50	83	0.51	86	0.61
Ecre/Esid	0.27	64	0.32	171	-0.98	233	0.32
Eeug/Etin	0.18	33	0.20	47	-0.42	78	0.68

Preferred koala food trees (PKFTs)

Analysis of variance (ANOVA) identified significant variation in the strike rates between species (F=10.50, 14_{df}, P<0.01). Two non-significant subsets were subsequently identified amongst the 15 species included in the analysis.

In order of decreasing strike rate Forest Red Gum *Eucalyptus tereticornis*, Tallowwood *E. microcorys* and Grey Gum *E. propinqua/E. biturbinata* were isolated as the most preferred species for koalas throughout Gold Coast LGA. Three additional species (Swamp Mahogany *E. robusta,* Red Mahogany *E. resinifera* and the Ironbark *E. dura*) were identified as overlapping with both the most preferred and less-preferred subsets (Figure 3.2).

Variation in strike rates for PKFTs across Regional Ecosystems (REs)

Within data sets large enough to be analysed with parametric methods, no significant differences were found in the use of PKFTs between the REs in which they were found. Some complex interactions were identified within the smaller data sets, investigation of which is beyond the scope of this study and, with the exception of those detailed below, had no influence on the subsequent classification of REs. Where significant differences were identified, these could be attributed largely to particular REs where little or no koala activity was recorded.

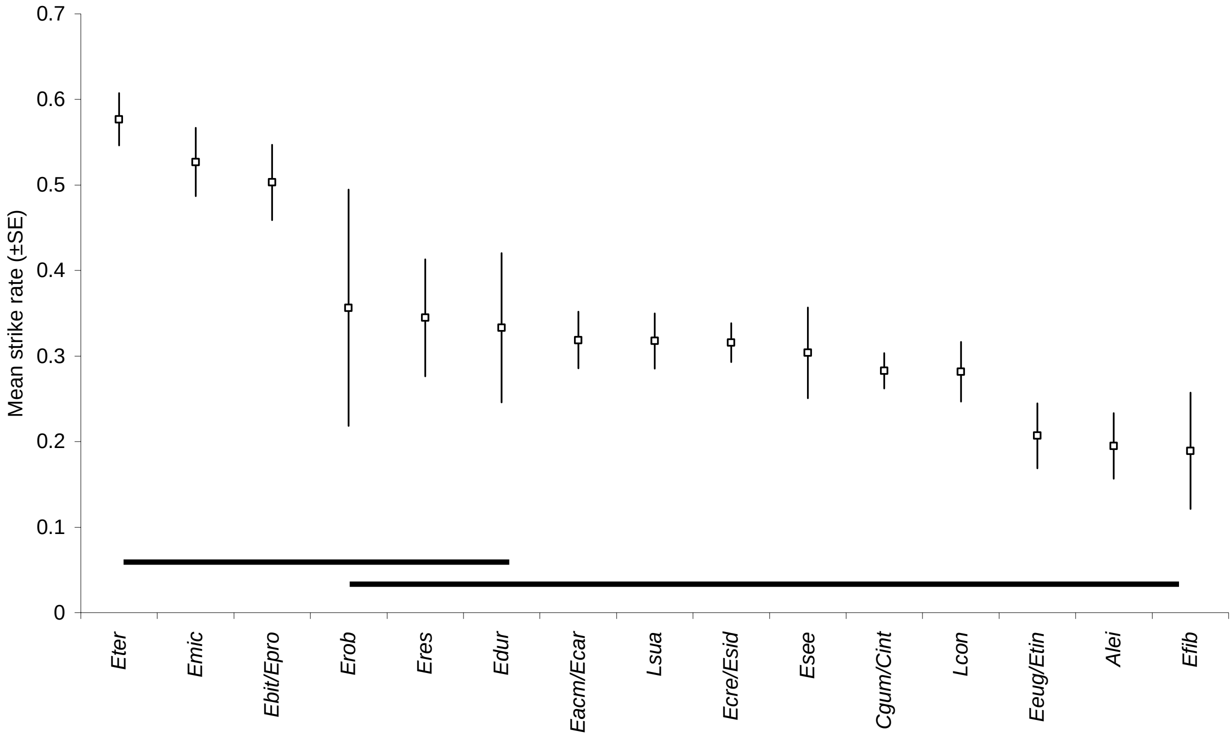

Figure 3.2. Mean strike rates for each tree species. Vertical bars represent ± standard errors. Horizontal lines indicate non-significant subsets resulting from the unplanned test for homogeneity using sum-of-squares simultaneous test procedures. *Eter=Eucalyptus tereticornis, Emic=E. microcorys, Ebit=E. biturbinata, Epro=E. propinqua, Erob=E. robusta, Eres=E. resinifera, Edur=E. dura, Eacm=E. acmenoides, Ecar=E. carnea, Lsua=Lophostemon suaveolens, Ecre=E. crebra, Esid=E. siderophloia, Cgum=Corymbia gummifera, Cint=C. intermedia, Lcon=L. confertus, Eeug=E. eugenioides, Etin=E. tindaliae, Acos=Angophora leiocarpa, Efib=E. fibrosa*

Eucalyptus tereticornis was sampled from 20 REs of which 15 met our criteria for analysis. There was no significant difference in the utilisation of *E. tereticornis* between REs in the parametric data set (F=1.27, 87_{df}, P=0.28). A lower level of utilisation was recorded within RE 12.3.3, however due to its restricted distribution within the LGA this interaction could not be investigated further. Accordingly, this RE was allocated to the category Uw in the subsequent koala habitat classification.

Eucalyptus microcorys occurred in 17 REs of which 12 were analysed for differences in strike rates. Two REs had sufficiently large sample sizes to be compared with a two-sample t-test. The strike rate for *E. microcorys* did not differ significantly between REs 12.11.5a/12.11.5j and 12.8.14 (t=0.44, 36_{df}, P=0.66). Variation between the remaining REs (n=10) was singularly attributable to a zero strike rate for *E. microcorys* within RE 12.8.1 wherein no koala activity was recorded.

Eucalyptus biturbinata/*E. propinqua* was sampled from 13 REs. Within the 7 sites used for analysis, strike rates varied between 0.05 and 0.68. When sampled from REs 12.11.5a/12.11.5j and 12.11.5k strike rates for the Grey Gums were not significantly different (t=0.65, 35_{df}, P=0.52). Variation in strike rates between the remaining REs was due to the low use of the species in association with RE 12.11.3a wherein this species was consequently excluded from consideration as a PKFT.

Koala density and population estimates

Evidence of habitat utilisation by koalas was recorded at 18 of the 44 primary sites. While representing a coarse estimate, this result suggests a current Area of Occupancy (AoO) of 41.0 ± 7.5%(SE).

Strip-transect searches (n = 44) covering a total area of 32.2 ha resulted in 3 koala sightings and an overall koala density estimate of 0.09 ± 0.04 koalas per ha. When extrapolated across the combined ~ 50,791 ha of mapped REs containing eucalypts, this results in an overall koala population estimate for the GCCLGA of 4,724 ± 208 (SE). With a 95% confidence interval applied, the estimated population size based on strip-transect surveys ranged from a lower limit of 4,316 to an upper limit of 5,131.

SAT-based searches (n = 95) involved a total area of 18.62 ha with 2 koala sightings and an overall population density estimate of 0.11 ± 0.03 koalas per ha. This resulted in an overall koala population estimate for mapped REs containing eucalypts of 5,435 ± 174 (SE). The 95% confidence interval for the

SAT-based koala population estimate ranged from 5,094 to 5,775. In common with outcomes from Part 2 of this report, these two koala density estimates do not differ significantly (t= -0.202, 86_{df}, P>0.05).

RE Koala Habitat Classifications

The proportional abundance of PKFTs in surveyed REs ranged from 53.3±10.2%(SE) for RE 12.8.8a to 3.1± 0.9%(SE) for RE 12.2.5, while being absent from REs such as 12.8.19 and 12.2.5/14. Figure 3.3 illustrates the variation in proportional abundance of PKFTs for each sampled RE. This data provided the basis for determining suitable abundance thresholds for each koala habitat quality category as indicated in Table 3.5.

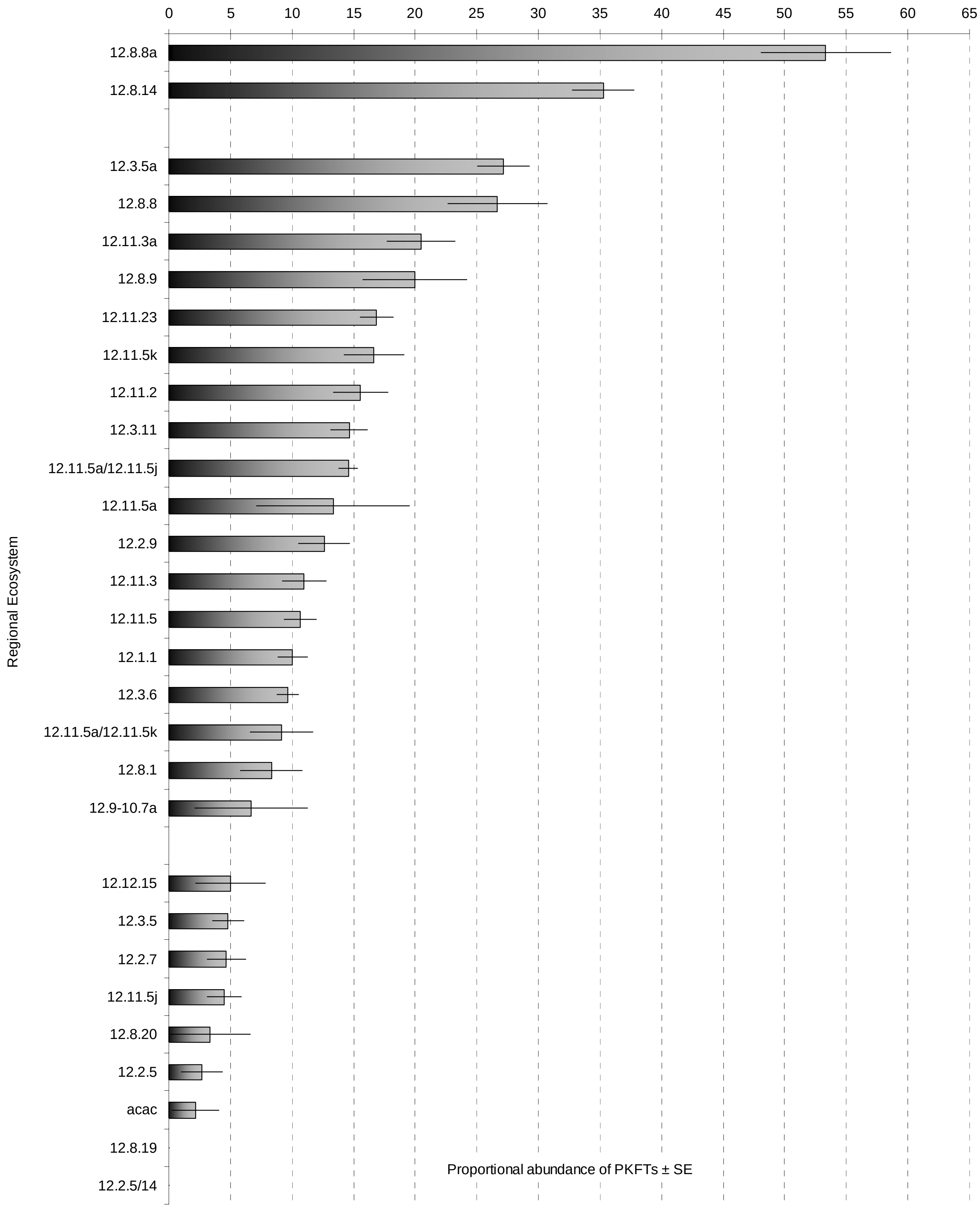

Figure 3.3. Proportional abundance of Preferred Koala Food Trees (± SE) for REs based on analysis of our field survey data.

Table 3.5. Criteria for classifying koala habitat quality for each RE based on expected abundance of Preferred Koala Food Trees (PKFTs).

Habitat Quality	Classification Criteria
A	≥35% PKFTs
B	<35% but >5% PKFTs
C	≤5% PKFTs
D	Eucalypt community with no PKFTs
E	Non-eucalypt community
Uw	Habitat quality unknown

Application of the decision rules for classifying REs within the GCCLGA resulted in a preliminary **Koala Habitat Quality Map** (Figure 3.4) which confirms that potential koala habitat (i.e. the combination of habitat quality categories A, B and C) is distributed widely across the LGA. The habitat quality classification for each RE is indicated in Appendix V.

The highest koala habitat quality category (A – Primary Koala Habitat) is limited to 2,548 ha of mapped REs, with the majority concentrated on slopes and ridges in the south-western section of the LGA (e.g., RE 12.8.8a *E. siderophloia*/*E. microcorys* forest at Springbrook and Lamington) and in smaller remnant patches or linear strips on floodplains and along watercourses (e.g. RE 12.3.3 *E. tereticornis* forest on alluvial plains). In contrast, a total of 43,095 ha (63%) of the mapped RE vegetation was classified as category B – Secondary Koala Habitat. The mapped area in hectares for each of the habitat quality classes is indicated in Table 3.6.

Table 3.6. Mapped area in hectares for each habitat quality class.

Habitat Quality	Area (ha)	% of total
A	2,548	4
B	43,095	63
C	4,774	7
D	374	<1
E	16,996	25
Uw	494	1
Totals	**68,281 ha**	**100 %**

Discussion

Habitat assessment surveys for the GCCLGA has resulted in a hitherto unprecedented dataset for the purposes of identifying and mapping koala habitat quality, estimating population abundance and Area of Occupancy across a heterogenous forest landscape.

With one exception, the results are unequivocal in terms of identifying PKFTs. Swamp Mahogany is widely recognised as an important koala food tree species in north eastern NSW and southeast Queensland (e.g. Phillips *et al.* 2000, Phillips 2000b, Lunney *et al.* 2000, Smith 2004). However the extent of clearing and development within coastal vegetation communities in the GCCLGA has reduced the occurrence of REs containing Swamp Mahogany to ~ 500 ha, much of which is now embedded in a disturbed urban landscape. It is therefore to be expected that koalas are absent from a number of the remaining vegetation patches where Swamp Mahogany occurs. Consequently, variance around the overall strike rate for this species was exaggerated by virtue of a high number of inactive sites which, in turn inferred an arguably unwarranted measure of importance to species such as *E. resinifera* and *E. dura*. In support of this, our survey results confirm that for areas such as Coomera Waters Estate, Swamp Mahogany clearly remains a key resource for koalas. Indeed, a final check of the habitat quality map against our field survey data resulted in two polygons of RE 12.3.5 being upgraded to Category A – Primary Koala Habitat on the basis that they were co-dominated by Swamp Mahogany, contrary to the RE description.

Our surveys have confirmed that koalas remain widely distributed throughout the GCCLGA hinterland. While relatively few koalas were actually sighted during this additional survey effort, significant koala activity levels (i.e. ≥ 22%) were widespread, even in areas such as the Hinze Dam catchment for which there are no historical records (following Part 4 refers).

Of the mapped koala habitat quality categories, Category B is the most prevalent within remaining larger, more contiguous vegetation patches and is likely to constitute the most significant category overall in terms of contribution to sustaining koala populations within the GCCLGA.

Key Outcomes

- The most preferred koala food tree species in the GCCLGA are Forest Red Gum *E. tereticornis*, Tallowwood *E. microcorys* and Grey Gum *E. biturbinata*/*E. propinqua*. Swamp Mahogany *Eucalyptus robusta* was heavily utilised in areas where koalas were present, has strong support for recognition as a PKFT in the literature, and was consequently regarded as a PKFT for habitat classification purposes.

- Koalas remain widely distributed throughout the GCCLGA hinterland. Density estimates varied from 0.09 - 0.11 koalas/ha and when extrapolated provide support for a population estimate of approximately 5, 000 occupying some 41% of the available habitat.

- A total of 45, 643ha of high-medium quality koala habitat has been identified based on the remnant RE mapping. Additional to the existing KHAs, areas of particular importance include relatively intact forest areas in the south-western section of the GCCLGA, central areas associated with Nerang State Forest and remnant bushland areas to the west of Ormeau and Beenleigh in the north.

Part 4

The Historical Record

Introduction

The historical analysis of community-based flora and fauna records is increasingly being used to inform management and conservation decisions. The koala has a high public and political profile such that it has already been the subject of several statewide and national surveys (Anon 1929; Kikkawa and Walter 1968; Campbell *et al.* 1979; Patterson 1996; Phillips 1990). Most recently, Gordon *et al.* (2006) utilized historical koala records to investigate changes in koala distribution in Queensland over the period 1881 - 2000, with particular reference to the south east Queensland bioregion wherein koalas were listed as a threatened species in 2004.

In this section we undertake an analysis of historical koala records for the GCCLGA with a view to addressing the following issues:

(i) the potential for changes in the spatial and/or geographic distribution of koalas within the GCCLGA over time,

(ii) using the concept of generational persistence, determining the extent to which the historical record may be capable of assisting/informing decisions relating to koala conservation by way of identifying important source populations, and

(iii) examining the relationship between historical records and the EPA's Regional Ecosystem mapping with a view to identifying any important habitat associations.

Methods

Koala records were solicited from a variety of sources including the Queensland Museum, EPAWildnet, Gold Coast City Council and National Koala Survey data. Once collated, records were sorted chronologically (by decade) and then checked individually for replication whereupon multiple records for the same location within a given decade were deleted.

The distributional parameters "*Extent of Occurrence*" (*EoO*) and "*Area of Occupancy*" (*AoO*) (Gaston and Lawson 1990; Gaston 1991) were used to quantify changes in the spatial and/or geographical distribution of koalas within the GCCLGA over time. To this end the historical *EoO* was determined as the total area (ha) enclosed by a Minimum Convex Polygon (MCP) derived by connecting the outer most of all koala records over time, followed by *EoO* determinations for each decade for which sufficient data was available. Examination of any changes in the related *AoO* was determined by creating a grid cell overlay within the historical *EoO*, randomly selecting a series of 5km x 5km (2,500ha) grid cells and enumerating the number containing/not containing one or more koala records in each instance. This process was repeated over 10 iterations for each time period examined and analysed using parametric statistics.

We coined the term “generational persistence” to describe the incidence of repeated sightings of koalas within a localized area over time spans that clearly involved three or more koala generations (16 – 24 years (Phillips 2000)), thus indicating the likely presence of resident and/or source populations; this being a mirror image of existing IUCN criteria which otherwise place weight on the concept of perceived population declines over a similar time period. For the purposes of this report, “localized” was considered to include that area defined by a 1km radius around each koala record, with generational persistence inferred by overlapping records occurring over the course of 3 or more consecutive decades.

Potential habitat associations of koalas were also examined using historical records. To assist this process, all independent records as determined above were intersected with the EPA’s Regional Ecosystem mapping (Version 5), our intent to identify any significant habitat associations that may assist future conservation and management planning. This data was also considered in the context of RE koala habitat classifications determined in the preceding chapter, specifically the relationship between the presence of koala records and that of preferred koala food trees.

Statistical analyses used in this section involved the use of one-way ANOVAs, *t*- tests, linear regression and log-likelihood ratios.

Results

Koala Records

Eight hundred and thirty six individual records were obtained. Once corrected for the presence of duplicate (or in some cases triplicate or quadruplicate) records – mainly arising from replication of EPA/NKS and EPA/Naturesearch/Wildnet data – there were 657 records remaining for analysis (Table 4.1, Figure 4.1).

Table 4.1. Source details for 657 koala records located within the GCCLGA over the period 1927 - 2005.

Source	No. of records
EPA Wildnet	379
Gold Coast City Council	264
NKS	7
Queensland Museum	7
Total	**657**

Chronology of sightings

The earliest recorded koalas in the GCCLGA stem from the Numinbah Valley during the 1920s. Three records for 1927 appear in the database, two of which are clearly the result of a duplicated record while the third is located nearly 2km away; in all probability however all three represent the same sighting.

Early translocations

During the course of investigations for this chapter we became aware of two historical translocation events within the GCCLGA. Both occurred over the period 1936 – 37 and involved 2 groups of 6 koalas being translocated from Boonah, Qld to the environs of Binna-Burra (a linear distance of approximately 70 kilometres) at a cost of 10/- (ten shillings)/animal. Documentary evidence regarding these translocations is apparently available in the form of correspondence and media articles from this period that are maintained in the Binna-Burra archives. The fate of these animals is unknown but it is unlikely they would have survived given differences between vegetation communities in the two areas.

The next record in the historical data does not appear until some 30 years later in 1957 from near Woongoolba. This is a valuable record as it is one of only a few that occurs in the north eastern section of the GCCLGA. After this, records through the 60s and 70s remain sparsely distributed and relate mostly to areas in the south of the LGA, notable amongst which is a single record for Southport and another for West Burleigh.

The period 1986 – 2005 sees the most significant increase in the number of records, including a single record for South Stradbroke Island and another from Point Danger. This latter record (Queensland Museum 1996) was subsequently removed from the data set given that it was the pick-up locality of a deceased animal, the origins of which were unknown. Figure 4.2 illustrates the trend in koala records over the period 1906 – 2005.

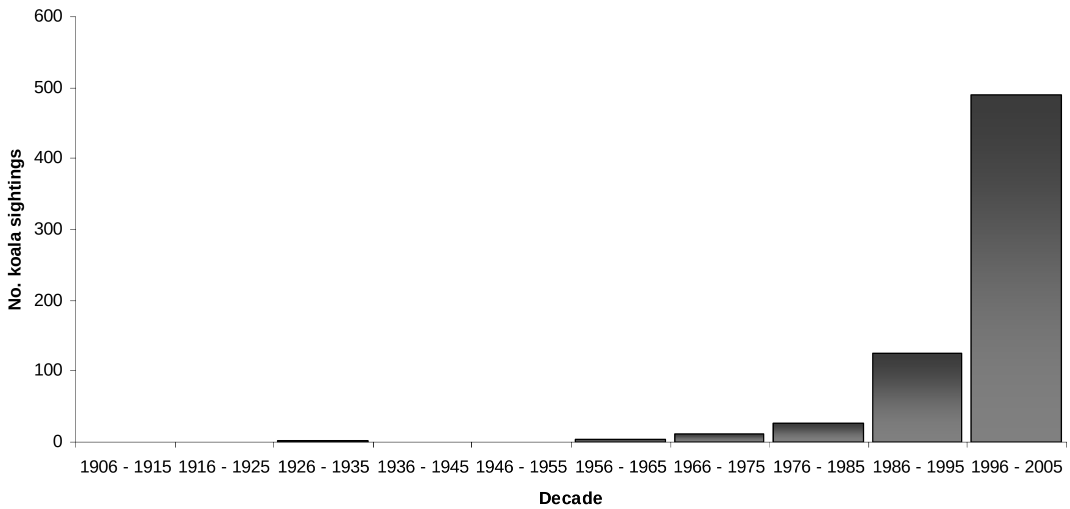

Figure 4.2. Chronological distribution of 657 koala records for GCCLGA over the period 1906 - 2005.

Extent of Occurrence

Available koala records for the GCCLGA reveal a historical *EoO* that approximates an area of 138,000ha, an area defined by a MCP that by definition must necessarily include a small strip of coastline and an area within the adjoining Beaudesert Shire. Given that these areas are a constant in calculations that follow, they do not detract from the overall trend in the data which otherwise evidences a gradual reduction in the *EoO* of approximately 13.6% over the last eighty years when changes in MCP areas for the last 3 decades are averaged and then compared to that obtained using all available records (Table 4.2). The reduction in *EoO* is most evident in the northeast of the GCCLGA and to a lesser extent in the southwestern corner (Figure 4.3).

Table 4.2. Percentage changes in the *Extent of Occurrence* of koalas in the GCCLGA based on comparing the areas of Minimum Convex Polygons derived by connecting the outermost of all koala records collected over the period 1927 – 2005 and those obtained over the last three decades respectively.

Period	No. records	EoO (ha)	% change
1927 - 2005	657	138,385	-
1976 - 1985	26	105,725	- 23.6
1986 - 1995	125	129,484	- 6.4
1996 - 2005	489	123,190	- 11.0

Area of Occupancy

Changes in the *AoO* are much harder to quantify. Over the period 1986 – 2005 there is clear increase in the probability of a koala record being present in any given 2,500ha grid cell, and hence it could be argued that there has also been a significant increase in the *AoO* during this time (F = 97.198, 29_{df}, $P < 0.001$). However, such an argument remains singularly supported by the substantive increase in the number of koala records for the period 1986 – 2005, a factor we attributed to two matters, firstly the inclusion of records arising from the 1987 National Koala Survey and secondly, listing of the koala as a threatened species in the south-east Queensland Bioregion in 2004; this latter factor in particular resulting in an increase in the reporting rate as evidenced by the various fauna survey reports from which most recent records are being sourced.

Hence the question remained – given the extent to which the historical data is skewed, is it possible to make any determinations about changes to the *AoO* over time? To examine this we undertook a comparison of koala records between the periods 1926 – 1975 (n = 44) and 1986 – 2005 (n = 613). Our procedure involved the random selection of 37 grid cells (~50% of study area) x 10 iterations for each of the two time periods, intersected by GIS with the corresponding historical records for each time period respectively. In order to deal with the disproportionately greater number of koala records for the period 1986 – 2005, each of the iterations we undertook for this latter time period was based on 44 randomly selected records in each instance. This approach returned the following results:

1926 – 1975
Mean *AoO* estimated at 34.9 ± 5.55% (SD) of the GCCLGA.

1986 – 2005
Mean *AoO* estimated at 25.6 ± 7.09% (SD) of the GCCLGA.

Analysis of the data sets supporting these outcomes confirms that within the GCCLGA there has been a statistically significant decline in the *AoO* over the last 20 years (t = 3.2670, 18_{df}, $P < 0.01$).

Generational Persistence

Evidence of generational persistence was widespread throughout the GCCLGA, effectively capturing an area of approximately 46,250ha in total. A brief account detailing the approximate location, size and koala history of these areas is as follows:

a) Burleigh Heads – West Burleigh

Koalas have been recorded from within an area of approximately 1,875ha over a period of at least 5 consecutive decades from 1956-65 through to 1996–2005.

b) Bahrs Scrub – Belivah

Koalas have been recorded from within an area of approximately 3,750ha over a period of at least 3 consecutive decades from 1976-85 through to 1996–2005.

c) Coombabah

Koalas have been recorded from within an area of approximately 14,062ha over a period of at least 5 consecutive decades from 1956-65 through to 1996–2005.

d) Coomera – Pimpama – Darlington Range

Koalas have been recorded from within an area of approximately 14,062ha over a time period of at least 4 consecutive decades from 1966-75 through to 1996–2005.

e) Currumbin Creek

Koalas have been recorded from within an area of approximately 3,125ha over a time period of at least 4 consecutive decades from 1966-75 through to 1996–2005.

g) Lamington – Numinbah – Springbrook

Koalas have been recorded from within an area of approximately 9,375ha over a time period of at least 4 consecutive decades from 1966-75 through to 1996–2005.

The locations and extent of those areas within which generational persistence is most evident are detailed in Figure 4.4.

Regional Ecosystem (RE) Mapping

Three hundred and one of the koala records that were available for analysis occurred within Version 5 RE mapping polygons. Of these, 295 were distributed amongst 41 of the 120 REs currently mapped for the GCCLGA (Table 4.3). A further 6 records were associated with non-RE polygons (sand, acacia regrowth, camp (Camphor Laurel), pine, plantation and urban respectively) and were consequently excluded from further analysis. When broadly aggregated (shaded rows in Table 4.3), more than half (~54%) of the 301 records were associated with only two REs – 12.11.3 and 12.11.5, which also happen to be those with the greatest proportional representation in terms of vegetation cover.

Table 4.3. Distribution of 301 koala records in terms of the EPA's Regional Ecosystem mapping for the GCCLGA (RE = Regional Ecosystem code; AggRE = aggregated landcover; RE KHC = RE koala habitat category as determined in the previous section). RE categories also include those mapped as disturbed.

RE	Area (ha)	AggRE(ha)	RE KHC	No. records
12.1.1	822.49		B	2
12.1.1/12.1.2	20.96		B	
12.1.1/12.1.3	7.18	850.63	B	
12.1.2	369.37		E	2
12.1.2/12.1.1	43.88		E	
12.1.2/12.1.2	574.99		E	
12.1.2/12.1.2/12.1.2	190.80		E	
12.1.2/12.1.2/12.1.3	9.76		E	
12.1.2/12.1.3	36.04		E	
12.1.2/12.2.15	7.21	1232.04	E	
12.1.3	4616.21		E	9
12.1.3/12.1.1	2.09		E	
12.1.3/12.1.1/12.1.2	1.18		E	
12.1.3/12.1.2	67.02		E	
12.1.3/12.1.3	370.33		E	
12.1.3/sand	1.32	5058.15	E	
12.11.18	87.49	87.49	D	
12.11.1	1390.35	1390.35	E	2
12.11.2	3344.64		B	1
12.11.2/12.11.3	143.41		B	
12.11.2/12.3.2	0.32	3488.42	B	
12.11.10	1144.36	1144.36	E	4
12.11.23	988.72		B	49
12.11.23/12.11.3a	229.51	1218.23	B	2
12.11.3	6862.01		B	33
12.11.3/12.11.2	138.69		B	
12.11.3/12.11.3	154.22		B	3
12.11.3/12.11.3a	399.30		B	3
12.11.3/12.11.9	16.88		B	3
12.11.3/12.3.7	46.68		B	
12.11.3a	1598.54		B	41
12.11.3a/12.11.1	51.88		B	
12.11.3a/12.11.3	11.22		B	
12.11.3a/12.3.1	11.51		B	
12.11.3a/12.11.5a	49.46	9340.39	B	
12.11.5	4486.66		B	6
12.11.5a	6646.90		B	33
12.11.5/12.11.5a	342.67		B	
12.11.5/12.11.5k	341.14		B	1
12.11.5a/12.11.3	116.19		B	
12.11.5a/12.11.3a	28.38		B	
12.11.5a/12.11.5	28.90		B	
12.11.5a/12.11.5j	1359.94		B	11
12.11.5a/12.11.5k	4838.41		B	5
12.11.5j	170.08		C	3
12.11.5k	2076.00		B	21
12.11.5k/12.11.5a	1425.20	21860.47	B	

12.11.9	250.15		A	3
12.11.9/12.11.5k	40.58	290.74	A	4
12.12.14	18.21		D	
12.12.14/12.12.15	24.76	42.96	D	
12.12.15	255.16		B	
12.12.15/12.12.14	267.32	522.48	B	
12.12.16	28.08	28.08	C	
12.12.19	4.42	4.42	E	
12.2.12	24.66		E	2
12.2.12/12.2.9	3.63	28.29	E	
12.2.14	190.55		E	2
12.2.14/12.2.16	61.70	252.25	E	
12.2.15	53.50		E	
12.2.15/12.3.5	3.92	57.42	E	
12.2.16	219.92	219.92	E	
12.2.2	0.68	0.68	D	
12.2.5	852.53		C	
12.2.5/12.2.14	106.99	959.52	C	
12.2.6	4.78	4.78	D	
12.2.7	224.26		C	1
12.2.7/12.1.1/12.2.5	470.41	694.67	C	
12.2.9	70.59		B	4
12.2.9/12.2.7	1.36	71.95	B	
12.3.1	97.10		D	
12.3.1/12.3.2	35.04		D	3
12.3.1/12.3.7	14.26	146.41	D	
12.3.11	840.42		B	5
12.3.11/12.11.9	1.46		B	
12.3.11/12.3.1	16.32		B	
12.3.11/12.3.6	21.73		B	
12.3.11/12.3.7	19.04	898.94	B	
12.3.13	4.43		E	
12.3.2	154.01		B	
12.3.2/12.3.1	71.89		B	
12.3.2/12.3.7	21.40	247.29	B	
12.3.3	3.45	3.45	A	
12.3.5	325.84		C	
12.3.5/12.1.2	5.29		C	
12.3.5a	419.82		C	5
12.3.5/12.3.5a	67.65		C	1
12.3.5/12.3.11	55.40	873.00	C	2
12.3.6	395.08		B	
12.3.6/12.3.11	28.37		B	
12.3.6/12.3.5a	26.69	450.14	B	
12.3.7	493.31		A	2
12.3.7/12.11.3a	4.27		B	
12.3.7/12.3.1	31.15		B	
12.3.7a	2.41	531.13	B	
12.3.8	66.26	66.26	E	
12.5.3	0.36	0.36	C	
12.8.1	857.49	857.49	B	3
12.8.14	779.36	779.36	A	10
12.8.16	10.18	10.18	B	
12.8.18	145.41	145.41	E	
12.8.19	211.06	211.06	D	

12.8.20	357.57		D	
12.8.20/12.8.19	16.83	374.40	D	
12.8.2	69.34	69.34	D	
12.8.3	3551.11		E	6
12.8.3/12.8.4	446.27		E	1
12.8.3/12.8.8	72.63	4070.01	E	
12.8.4	122.50		E	
12.8.4/12.8.14	21.47	143.97	E	
12.8.5	1177.68	1177.68	E	3
12.8.6	30.04	30.04	E	
12.8.8	1518.66		B	1
12.8.8/12.8.1	51.90		B	1
12.8.8/12.8.8a	219.96		B	
12.8.8a	943.48	2733.99	A	6
12.8.9	783.93	783.93	B	1
12.9-10.19a	3.78	3.78	D	
12.9-10.4	20.02	20.02	C	
12.9-10.7a	90.07	90.07	B	
Other	4709.82	4709.82	n.a.	6
TOTAL	**68281.59**	**68281.59**		**301**

Regression analysis of data contained in the preceding table suggested a positive relationship between the numbers of koala records and the area of aggregated RE land cover (Figure 4.5). While this result has statistical support (r^2 = 0.6334, F = 38.021, P < 0.001), the inferred relationship is not strong with only slightly more than 60% of the variance explained by analysis. For this reason we chose to undertake further analyses by firstly splitting the RE data into two broad categories in accord with outcomes of the previous section, namely "A+B+C" and "D+E", the difference being whether or not preferred koala food trees *E. microcorys*, *E. propinqua* and *E. tereticornis* were present or absent respectively. Of these two data sets, category "D+E" collectively comprised the smaller area (17,370ha). We then randomly sampled (with replacement) 100 koala records for each of 10 iterations and determined the number of those occurring within habitat category "A+B+C". This process was repeated for category "D+E". An upper area limit was set on habitat category A+B+C by randomly selecting polygons to a total of 17,370ha. Controlling for area, this analysis revealed that on average koala records were at least 5 times more likely to occur in REs that contained preferred koala food trees when compared to those that did not (t = 15.4612, 18_{df}, P < 0.001). Thus, while the larger the area covered by a given (aggregated) RE infers a larger number of koala records, the presence of preferred koala food trees significantly increases the probability of such records being present. This is a key outcome which underpins the importance of retaining preferred koala food tree species in the landscape, regardless of patch size and/or the extent of forest cover. Another way of demonstrating this relationship is provided in Table 4.3 where we have simply compared the 120 REs within the GCCLGA in terms of the extent to which koala records are associated with the abovementioned habitat categories; while a less robust analysis than that carried out above, the results are none the less significant (G = 5.311, 1_{df}, P = 0.0212).

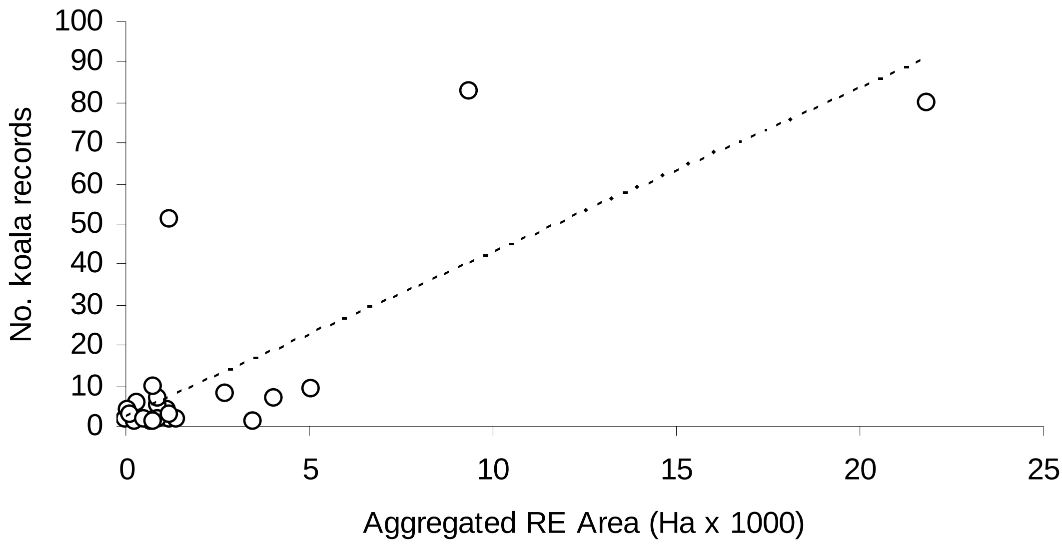

Figure 4.5. Relationship between the number of hectares of aggregated RE landcover (x-axis) and the number of koala records.

Table 4.3. Provided in the form of a 2 x 2 contingency table, the association between koala records and Regional Ecosystems as a function of whether preferred koala food trees were present (A+B+C) and those wherein preferred koala food trees were absent (D+E) The A – E categorisation of Regional Ecosystems is detailed in the preceding chapter.

	A + B + C	**D + E**	**Totals**
Koalas present	31	10	**41**
Koalas absent	43	36	**79**
Totals	**74**	**46**	**120**

Discussion

This section has revealed that a careful analysis of historical koala records has the potential to inform conservation and planning decisions. From a relatively small and chronologically skewed data set of 657 records we have been able to quantify changes in the spatial/geographic range parameters of koalas over time, identify potentially important source populations and corroborate the important relationship between koalas and those Regional Ecosystems that contain preferred koala food tree species.

An inherent problem associated with survey data such as historical records is that they are essentially observer-biased and do not represent the results of a systematic survey effort. Hence, quantitative range parameters such as the *EoO* and *AoO*, and concepts such as generational persistence will invariably underestimate the full extent of change (positive or negative) and the potential locations of source populations respectively. This issue becomes particularly pertinent when examining recent koala records arising from targeted surveys such as those carried out at Currumbin Waters in 1997 (AKF 1998) and Warrego Way, Helensvale in 2004. Accordingly, dense clusterings of records resulting from such localised surveys should be interpreted with caution. It is with these considerations and limitations in mind that the following key outcomes are presented.

Key Outcomes

- The historical record indicates that koalas have a long history of occupation in the GCCLGA. The number of records available for analysis has increased substantively over the last 20 years in particular, a fact we attribute to the 1987 National Koala Survey and more recently the listing of koalas as a threatened species in the SEQ bioregion.

- Consideration of all historical records indicates that a reduction in the *Extent of Occurrence* of koalas within the GCCLGA of approximately 14% has occurred over the last 80 years. Range reduction has been most apparent in the north east and south western corners of the GCCLGA. Changes in the associated *Area of Occupancy* over this time frame further support this trend, analysis revealing a significant reduction over the last 20 years.

- Notwithstanding the above, analysis of the historical record in terms of generational persistence reveals several areas within the GCCLGA that contain viable, free ranging koala populations. Thus koalas continue to maintain a widespread distribution within the GCCLGA, a factor we primarily attribute to the topographically diverse hinterland of the GCCLGA in particular.

- Intersecting the historical records with RE mapping confirms a strong association with REs containing trees of the Genus *Eucalyptus* and there was a positive linear relationship between the numbers of koala records and the total area of aggregated RE vegetation cover. However, koala records were 5 times more likely to occur in REs that contained preferred koala food tree species, thus confirming the overriding importance of conserving preferred koala food trees across the planning landscape.

Part 5

Koala Habitat Areas

Preamble

As outlined in Part 1 of this report, Koala Habitat Areas (KHAs) can include Koala Conservation Areas (KCAs), Koala Sustainability Areas (KSAs) and Urban Koala Areas (UKAs). In identifying such areas, the *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006 – 2016* (the KCP) requires that consideration be given to relevant planning outcomes or objectives contained in Local Government strategic planning documents and/or the SEQRP, particularly when proposing additional KSAs or UKAs within the SEQRP's urban footprint. To this end, any Local Government koala habitat assessment study and associated Koala Habitat Area mapping requires endorsement by both Council's chief executive and State Government and does not have effect until it is reflected in a temporary Local Government planning instrument or planning scheme. Once endorsed, the Koala Habitat Map has the effect of triggering the assessment of development applications against koala conservation criteria outlined in the KCP, with the EPA as a concurrence agency for development applications involving any new KCAs or KSAs.

As set out in Policy 7 of the KCP, KCAs can be located within Regional Landscape and Rural Production Areas (as defined by the SEQRP) with the specific aim of identifying critical source areas for survival and dispersal of koalas across the landscape. Accordingly, the KCP describes KCAs as being large areas of relatively intact remnant or regrowth *Eucalyptus*-dominated forest or woodland containing high koala habitat value and/or koala densities (relative to the LGA). KCAs can include cleared or fragmented areas, but are generally expected to have a high level of patch connectivity, to contain a mosaic of private and public lands and park estate with limited urban development and infrastructure. KSAs are described as having similar features to KCAs, but are restricted to habitat areas that fall within the Urban Footprint and Rural Living Areas identified by the SEQRP. KSAs may contain open space areas and existing rural residential development. UKAs can include scattered eucalypts and small habitat patches of high conservation value (to koalas) that, like KSAs, are located in residential areas or areas with urban intent within either the Urban Footprint or Rural Living Areas.

This part details the decision path we applied in order to identify and map KHAs throughout the GCCLGA, a process informed by work undertaken in the preceding parts but additionally involving application of a RE-based Habitat Assessment Matrix. The KHAs presented herein are underpinned by a set of recommendations and guidelines for ongoing management of koala populations and koala habitat within the GCCLGA generally.

Koala Habitat Assessment Matrix

Part 3 of this report provided a hierarchical classification of koala habitat based on consideration of the proportional abundance of PKFTs within the various REs that collectively constitute the remaining native vegetation cover in the GCCLGA. In order to better understand the role of the various REs in terms of both their size and location in the landscape, we further classified them in accord with a habitat quality/size class matrix (Table 5.1) as detailed on the following page. Application of this matrix-based approach results in a more complex map of koala habitat than that presented in Part 3, the advantage of which is that the extent to which REs of importance to koalas make up individual forest patches in the landscape can be more readily interpreted, as can the role and juxtaposition of less important REs in terms of assisting connectivity. Hence, for the purposes of identifying KHAs, the role of both individual and/or aggregated REs that contain PKFTs becomes more apparent. Table 5.1 is followed by a contained discussion of associated issues related to KHAs in general, along with matters such as connectivity that we needed to consider as a part of this process.

Table 5.1. Koala habitat assessment matrix for the GCCLGA based on a size-class based classification of Regional Ecosystems. Shaded cell groupings indicate focal areas for consideration as potential KHAs (PKFTs = Preferred Koala Food Trees).

KOALA HABITAT QUALITY	REGIONAL ECOSYSTEM LANDSCAPE STRATUM			
	1 Large Polygons (>100 ha)	2 Medium Polygons (51 - 100 ha)	3 Small Polygons (10 – 50 ha)	4 Small Stands (< 10ha)
A Primary Koala Habitat (PKFTs ≥35%)	A1	A2	A3	A4
B Secondary Koala Habitat (5%< PKFTs <35%)	B1	B2	B3	B4
C Tertiary Koala Habitat (PKFTs ≤5%)	C1	C2	C3	C4
D Supplementary Koala Habitat (no PKFTs, but other eucalypts)	D1	D2	D3	D4
E Other Vegetation (no eucalypts)	E1	E2	E3	E4

Koala Habitat Areas - some key considerations

Koala conservation should ideally be based not only on scientifically sound assessments in the first instance, but also the application of solid landscape ecology/conservation biology theory. In this context two issues arise. Firstly, there is the matter of area and exactly how much land is required to sustain a free-ranging population in perpetuity. Secondly, there is the issue of connectivity; important initially in the context of describing landscape patches *per se*, and latterly in terms of how open space limits the probability and/or likelihood of movement of koalas between patches themselves.

Koala Habitat Areas – how big should they be?

Based on koala density data detailed in the Part 3, we determined that a KHA should ideally include a minimum area of approximately 1,500 ha of reasonably well-connected, high-quality koala habitat in order to sustain a Minimum Viable Population of ~170 koalas while also allowing for a minimum occupancy rate of approximately 50% of available habitat in order to accommodate meta-population expansion and contraction.

Connectivity and RE patches

RE polygons that contained PKFTs were considered **connected** only if they were co-joined or **linked** by other REs and/or native vegetation communities that did not contain PKFTs.

Connectivity and koala movement

For this purpose we considered REs to be connected if there was a distance of no more than 500m between aggregated RE patches that contained PKFTs.

We used the map resulting from our filtering of REs through the Koala Habitat Assessment Matrix (Figure 5.1) as the primary basis for identifying potential KHAs within the GCCLGA**.** Our initial steps in this process focused on a cursory identification of likely management "precincts" based on what we perceived to be major barriers to koala recruitment and dispersal, followed by consideration (refer to box on preceding page) of koala population/habitat values and landscape elements, irrespective of cadastre and strategic planning objectives. Outcomes from these processes were then considered in terms of the statutory impositions of the SEQRP.

The decision path and procedures we followed are outlined below:

Step 1: Management Precincts

Management precincts were identified within the GCCLGA based on primary barriers to koala dispersal and recruitment processes. For the purposes of this study, such barriers were deemed to be the Pacific Motorway and Gold Coast Highway along with all 4^{th} order and above rivers or streams.

Step 2: Koala population/ landscape element consideration

This step involved consideration of two issues, the known presence of source populations (Part 4 refers) and the amount of habitat required to support at least the MVP of ~170 koalas. As demonstrated below, by also considering both the number and size of aggregated patches constituting the 1,500 ha of koala habitat in each instance we also considered it desirable to be able to aportion a Level of Fragmentation (Low – Medium – High) to each potential KHA, thus enabling identification of areas wherein restoration and/or rehabilitation works would be of greatest value. These concepts were embedded in the following 4 questions:

1. Within each of the identified precincts, was there evidence of generational persistence? (If yes go to Question 2, if no go to Step 6).

2. Was there ~1,500 ha of habitat (i.e. habitat assessment matrix categories A1, A2, A3, B1, B2, B3, C1 or C2 in the form of either a single RE patch or a co-joined patch of aggregated REs? (If yes, Level of Fragmentation "Low", go to Step 3, if no go to Question 3).

3. Was there ~1,500 ha of habitat in the form of 2 to 4 relatively large (i.e. ≥250 ha each), co-joined and/or linked patches of aggregated REs that contained PKFTs? (If yes, Level of Fragmentation "Medium", go to Step 3, if no go to Question 4).

4. Was there ~1500 ha of habitat in the form of more than 4 co-joined and/or linked patches of aggregated REs that contained PKFTs? (If yes, Level of Fragmentation "High", go to Step 3, if no go to Step 6)

Step 3: Boundary rationalisation

In order to ensure the required conformity with the GCCLGA cadastre, the following approach was adopted:

1. Individual properties were incorporated whenever they contained or overlapped with part of either a single RE patch or a patch of aggregated REs that formed the basis of the decision reached in response to Step 2 (Questions 2 – 4) above.
2. Properties that contained any outlying single or aggregated RE patches containing PKFTs that were ≥50ha and within 500m from the edge of vegetation identified in 1 above were also incorporated, together with any intermediate properties.
3. In the case of inholdings and/or inward projections, properties were excluded once the distance between aggregated REs identified in Step 2 above became greater than 500m.

Step 4: KSA identification

Where aggregated RE patches identified in Steps 2 and 3 were contained within the SEQRP's Urban Footprint, co-joined or linked habitat matrix classifications of A(1-3), B(1-3) and C(1-2) were deemed to warrant classification as KSA.

Step 5: UKA identification

Where aggregated RE patches identified in Steps 2 and 3 were contained within the SEQRP's Urban Footprint, co-joined or linked habitat matrix classifications of A4, B4 and C(3-4) were delegated to UKA where they were located at a distance of 500m from any area identified in Step 4 above and/or were clearly located within an already urbanized landscape. Additionally and for buffering purposes, UKA classifications were routinely applied within the SEQRP's Urban Footprint for a distance of approximately 500m (or to the nearest logical cadastral boundary) from the outer edge of any area identified as either KSA or KCA .

Step 6: Safety Net

This last step in our process of KHA identification required us to re-examine any areas that were excluded by Step 2, whereby a negative response to Question 1 therein may have resulted in large areas of potential koala habitat slipping through the filter simply because of a lack of evidence of generational persistence. Conversely, it was also possible that areas with evidence of generational persistence had also slipped through the filter for want of the required area of aggregated habitat (Step 2, positive response to Question 1 but negative response at Question 4).

Proposed KHAs

Implementation of the above decision path results in our preliminary **Koala Habitat Area Map** for the GCCLGA (Figure 5.2) which clearly reflects the extensive distribution of koalas and their habitat otherwise alluded to in Parts 3 and 4 of this report. While appearing to broadly encompass much of the remaining forested areas in the central and western parts of the GCCLGA within a single KHA, the Koala Habitat Map proposes six new KHAs, three of which extend into the adjoining Beaudesert Shire, while others are likely to be connected at higher elevations. In this latter context, given that the greater parts of such KHAs are largely separated from each other by major watercourses at lower elevations, we considered it prudent to maintain a measure of management independence. Accordingly, Table 5.2 summarises the key attributes of each proposed KHA based on the size and extent of remaining koala habitat, with koala population estimates derived from overall LGA occupancy rates and density estimates as presented in Part 3.

Table 5.2. Key features associated with each of the proposed new Koala Habitat Areas.

KHA	AREA (ha)	KCA (%)	KSA (%)	UKA (%)	PKH (ha)	LoF	PKFTs	GP	No. Koalas	Long-term Prognosis
Bahrs Scrub*	3,970	45	32	23	1,468	High	Eter, Emic, Epro	Yes	117 - 205	Good
Coomera West*	16,611	79	14	7	10,122	Low	Emic, Epro, Eter	Yes	810 - 1417	Good
Nerang*	16,534	84	11	4	9,773	Med	Eter, Emic, Epro/Ebit	Yes	782 - 1368	Good
Hinze Dam/S'brook	24,433	82	12	6	16,704	Low	Emic, Epro/Ebit, Eter	Yes	1336 - 2339	Excellent
Tally Valley	7,810	80	13	7	3,721	Med	Emic, Epro, Eter	Yes	298 - 521	Excellent
Burleigh Heads	707	11	66	23	168	High	Eter, Erob	Yes	13 - 25	Poor

KCA = Koala Conservation Area; KSA = Koala Sustainability Area; UKA = Urban Koala Area; LoF = Level of Fragmentation; GP = Generational Persistence; PKFTs = Preferred Koala Food Trees; PKH = Potential Koala Habitat; No. Koalas = estimated number of koalas as a function of the amount of PKH, ~41% occupancy and estimated density of ~ 0.08 – 0. 14 koalas per hectare; Long-term Prognosis: Poor = < 25 years; Good = > 25 years; Excellent= > 50 years.
* = share a common boundary with adjoining Beaudesert Shire LGA.

1. Bahrs Scrub KHA (Figure 5.3)

Located in the extreme north-west of the GCCLGA, the proposed KHA is bordered in the north and east by the GCCLGA/Logan City LGA boundary and the Pacific Motorway respectively, to the south by the Logan River and in the west by the GCCLGA/Beaudesert Shire boundary.

2. Coomera West KHA (Figure 5.4)

Located to the south of the proposed Bahr's Scrub KHA, this proposed KHA is bordered by the Pacific Motorway in the east and by the Logan and Coomera rivers to the north and south respectively, sharing a western boundary with Beaudesert Shire.

3. Nerang KHA (Figure 5.5)

Extending deep into the Numinbah Valley, this proposed KHA is bordered by the Pacific Motorway in the east and by the Coomera and Nerang rivers to the north and south respectively, again sharing a western boundary with the adjoining Beaudesert Shire.

4. Hinze Dam – Springbrook KHA (Figure 5.6)

Bordered in the east by SEQRP's urban footprint, this proposed KHA lies between the Nerang River and Tallebudgera Creek, extending in a south westerly direction to the NSW/Qld border.

5. Tally Valley KHA (Figure 5.7)

Bordered in the east by the urban centres of Elanora/Palm Beach, this proposed KHA lies between Tallebudgera Creek in the north and the NSW/Qld border to the south and west.

The remaining KHA resulted from considerations arising from Step 6 whereby despite evidence of generational persistence over a period of at least the last 5 decades, little in the way of adequate habitat remains to support the population. Consequently, the proposed Burleigh Heads -Tallebudgera KHA (Figure 5.8) has been identified as a locality warranting special management attention within which conservation effort could be focused primarily through community education, planting of preferred koala food trees and responsible dog ownership and motor vehicle use.

Implications

Notwithstanding the need for due consideration of the proposals contained herein by Gold Coast City Council, EPA and the OUM, a number of issues arise that remain independent of any subsequent modification and/or approval of the KHA proposals detailed in the preceding section. The primary implications are as follows:

1. There are substantive areas of koala habitat which contain resident koala populations that are captured by the SEQRP urban footprint within the proposed Bahr's Scrub, Coomera West, Hinze Dam – Springbrook and Tally Valley KHAs. Regardless of any subsequent amendments to the classifications we have proposed for these areas, they will require more detailed field assessments and the likely development of area-specific management strategies in order to ensure that the potential for a significant negative impact upon resident koala populations is minimized.

2. It is also clear that important areas of koala habitat are likely to be present within the adjoining Beaudesert Shire. Hence logistical and financial support from the EPA to enable a comparable koala habitat and population assessment study for this LGA should be afforded a high priority in order to assist koala conservation measures within the GCCLGA.

3. Our proposal for a Burleigh Heads-Tallebudgera KHA demands recognition that the koala population in question is an iconic, long-standing and internationally recognized natural asset within the Burleigh Heads area. It would thus be a great tragedy were this population to succumb to localized extinction. Hence the need for a comprehensive assessment of this population, along with an appropriately informed management response and community

education program, one aspect of which must be the identification of opportunities and/or actions to facilitate survival of the population in perpetuity.

Conclusion

The GCCLGA has a large and topographically diverse hinterland that supports extensive areas of *Eucalyptus* dominated forest and/or woodland, much of which contains PKFTs. Our data suggests that approximately half of this area also supports resident koala populations, the collective size of which we have estimated at approximately 5,000 individuals. Fortunately, while the very nature of much of the GCCLGA hinterland makes it unsuitable for intensive development, it appears very suitable for achieving koala conservation outcomes. The obvious question that arises is whether (or not) koalas have a secure future within the GCCLGA, to which our qualified response would be in the affirmative. Having said this, we remain mindful that about 15% of the estimated population is essentially isolated in three sub-populations east of the Pacific Motorway, none of which have a guaranteed future. The remaining 85% survive in an increasingly fragmented habitat matrix that is compartmentalised by road and water barriers, each with differing levels of threat that range from development pressure at the urban/bushland interface, road strike, ongoing habitat loss and increases in fire frequency and intensity. In short, there are no grounds for complacency and it will only be by effectively managing each of the parts that the whole will be preserved. In order to further assist this process, the following pages provide a discussion on the need for more stringent planning measures within KHAs generally, but with a particular emphasis on the ever expanding urban/bushland interface.

Incorporating KHA mapping into Local Government planning

The KCP requires that once the koala habitat assessment and mapping study has been approved by Council, it is to be forwarded to the State Government requesting endorsement and amendment of State Koala Habitat Areas Map. This request is to be accompanied by an outline of the timetable for adopting the koala habitat mapping via either a temporary local planning instrument or the Local Government planning scheme, consistent with requirements of the *Integrated Planning Act*. Once this has been achieved, the mapping will trigger assessment of development applications against the Koala Conservation Criteria for both State and Local Government development assessment processes.

The Koala Conservation Criteria apply to types of development activities specified in the KCP (such as material change of use other than a ‘domestic activity’, reconfiguring a lot, or operational work) that are proposed in KHAs and made assessable by virtue of Schedule 8 of the *Integrated Planning Act*, a Local Government planning scheme, or the regulatory provisions of the SEQRP. The criteria also apply to proposed community infrastructure designations. *Policy 1: Koala sensitive development* of the KCP is referred to in the criteria for further advice on measures to help achieve compliance with the SEQRP’s Koala Conservation Policy.

This section outlines specific criteria for consideration when assessing development applications with respect to KHAs within the GCCLGA. These measures aim to further:

i) Consolidate retained habitat amongst adjoining developments to maximise the size, quality and landscape connectivity values of habitat patches;

ii) Minimise the chances of koalas being killed or injured during clearing operations;

iii) Minimise threats to koalas moving through intensively developed areas, particularly those adjacent to protected habitat; and

iv) Minimise the likelihood of koalas being attracted into intensively development residential areas where threats from traffic and dogs are likely to be high.

A. *Prima facie* requirements

1. In addition to the abovementioned aims, Council should ensure that the KCP's desired outcomes for KHAs are adequately reflected in all relevant planning instruments and strategic planning documents.

2. All relevant planning instruments and strategic planning documents should also require development applications to demonstrate that they have incorporated measures to ensure compliance with the Koala Conservation Criteria in addition to the following specific criteria.

B. Recommended specific criteria relating to general committed development and uncommitted future development in KHAs

1. Native forest areas to be retained should be selected with consideration of adjoining habitat areas in order to avoid retention of small, isolated habitat patches, but rather to maximize habitat quality and landscape connectivity values (see following "*Guidelines for prioritising habitat areas for protection"*). Ideally, habitat protection areas should seek to embellish already designated habitat linking or corridor areas and large blocks of protected habitat, particularly any that adjoin a KCA or KSA. The permanent protection and ongoing management needs of such consolidated habitat protection areas should ideally be addressed through a body corporate title agreement or Voluntary Conservation Agreement.

2. Ensure that habitat linking areas and consolidated habitat patches focus on areas of high quality koala habitat (see Part 3) so that carrying capacity is maximised, together with the likelihood of attracting any dispersing koalas away from intensively developed areas. For sites that lack connected patches of native vegetation and high quality koala habitat,

habitat links and consolidated habitat patches should seek to incorporate scattered PKFTs if present on site.

3. More stringent koala sensitive development and design criteria should be implemented within a minimum 50-100m wide *Koala Sensitive Development Zone* (KSDZ), defined by practical boundaries such as streets, wherever residential development adjoins the outer edge of habitat linking areas and consolidated habitat protection areas such as those outlined above. In the case of future uncommitted developments in KCAs and KSAs, the following measures should ideally be applied across the entire development site. Development and design criteria should include:

- Maximum retention of PKFTs.
- Larger lot sizes (e.g. ≥2000 m^2) wherever feasible.
- Prohibition on the keeping of domestic dogs by way of covenant or other restriction on user linked to property title.
- Required provision and maintenance of ≥30cm gaps under all property boundary fences to minimise restrictions to koala movement by way of covenant or other restriction on user linked to property title.
- Enforced restriction of traffic speeds to 40 km/h throughout KSDZs, using vehicle calming devices and signage to mitigate speed wherever practicable.
- Location of all through-roads and arterial roads outside of KSDZs.
- Location of arterial roads and through-roads should avoid traversing habitat linkage and/or habitat protection areas unless unavoidable, in which case exclusion fencing and regularly spaced underpasses (i.e., 50m to 100m intervals) should be installed throughout the extent of habitat. Where underpasses are not practicable due to topographic constraints, regularly spaced fauna crossing points should be provided in conjunction with slow speed zones, traffic calming measures, signage, lighting and/or suitable road surface treatment.
- Ensuring that swimming pool fencing is designed and positioned to keep both children and koalas safely out.
- The direction of street lighting downwards and away from the edge of habitat linkage and/or habitat protection areas.

4. Where KSDZs are not possible, consideration should be given to the incorporation of one-way koala exclusion fencing along the edge of habitat linking areas so as to allow koalas to enter the linking habitat from the developed area, but to prevent movement from linking habitat into the developed area. Concepts and/or design specifications for one-way koala exclusion fencing can be supplied if so required.

5. Vegetation or habitat management and restoration plans should be prepared and implemented for all consolidated habitat protection and habitat linking areas. Options for seeking developer contributions for compensatory habitat protection and/or restoration measures should also be fully explored.

6. Use of PKFTs for streetscape or landscape plantings should be prohibited within future urban areas beyond habitat linking areas, consolidated habitat patches and KSDZs, the aim being to minimise the chances of drawing koalas into high-threat environments.

C. Koala management during clearing and construction operations

1. In the case of UKAs, for any parts of a development site where existing development commitments or future approvals permit the removal of the majority of native vegetation, the retention of preferred koala food trees should be maximized during the course of initial clearing activities. This would aim to ensure that essential food resources for resident koalas are retained over the short-term.

2. Any koalas spotted during clearing activities should be afforded a minimum 50m buffer and should be reported immediately to Council.

3. Koalas spotted during clearing activities should be allowed to leave the area of their own volition, unless part of an EPA-approved research program.

D. Shire-wide koala habitat restoration and management

1. A Shire-wide koala habitat restoration and management program should ideally be prepared with reference to each of the identified KHAs, particularly those assigned a high or medium level of fragmentation (see Table 5.2). This program could be prioritised to focus on areas mapped as cleared and/or disturbed within each KHA, linked to an incentives scheme for discussion with private land-holders that may be prepared to secure the permanent protection of areas on their property in return for assistance with habitat restoration and potential financial incentives. Permanent protection would need to be assured via means such as Voluntary Conservation Agreements or Property Management Agreements.

Guidelines for prioritising habitat areas for protection

The following considerations are based on "*Planning Guidelines for Koala Conservation and Recovery - a guide to best planning practice*" prepared by the University of Queensland, Australian Koala Foundation and the NSW Department of Environment and Conservation (McAlpine *et al.* 2007). These considerations have been taken into consideration in the process of identifying Koala Habitat Areas across the Gold Coast LGA. They provide support for a number of the actions we have recommended and guidance for prioritising areas for protection within KSAs and UKAs.

1. **Habitat thresholds**. Evidence from research in Noosa Shire has indicated that the probability of koalas being present falls as the percentage of the landscape containing forest communities (including preferred koala habitat) falls below ~ 40% to 60%. These percentages provide useful overall targets for habitat protection and restoration.

2. **Patch size**. Evidence from fragmented coastal landscapes in Noosa Shire indicated critical patch size requirements, with koalas 50% less likely to be present in patches less than ~ 50 ha in size. There was also some evidence to suggest that the chance of koalas being present starts to decline once patches become smaller than ~ 150 ha. Hence, priority should be given to protecting patches of preferred koala habitat larger than ~ 50 ha in size, unless part of a cluster of highly connected patches.

3. **Patch shape**. Habitat patches should ideally be more circular than linear in shape in order to minimise edge effects. Edge effects might affect koalas by, for example, increasing the risks of predation by roaming dogs or decreasing the health of preferred food trees. As habitat patches become smaller, the amount of edge, relative to the area of each patch (the perimeter-area ratio) increases. Therefore, small patches are generally more subject to edge effects than large patches. For a given patch size, the amount of edge is smallest for a circular shape, but largest for a narrow linear shape.

4. **Connectivity**. If habitat patches are close enough to each other for koalas to move freely between them they may be adequately connected for koalas, providing there are no major barriers such as roads, fences, or significant threats such as wild dogs, roaming domestic dogs or traffic. In general, koalas would be expected to undertake regular home range movements between habitat patches if they are separated by distances no greater than ~ 100 m and provided there are no significant barriers or threats. Although koalas are relatively mobile, isolation of patches can be an important predictor of koala occurrence, with koalas more likely to occur in patches close to other patches than in isolated patches. Programs to maintain or enhance connectivity should aim for a network of larger habitat patches linked by corridors at least 100m wide, but preferably wider to minimise edge effects.

   Small populations that are highly isolated tend to suffer much higher extinction risks than populations that are connected to each other via animal movement. Immigration or recruitment into a population can provide a 'rescue' effect and can help maintain genetic diversity. The survival of meta-populations (a group of sub-populations connected by dispersal) relies on the ability of animals to recolonise habitat patches where a sub-population has become locally extinct. Whilst habitat patches that are further apart are often considered less connected than patches close together, connectivity also depends upon the nature of the matrix (i.e., the most extensive landscape element, generally cleared areas between vegetated patches in highly fragmented landscapes), and the existence of barriers to movement.

5. Priority should be given to **restoration programs** intended to enlarge the size of remnant koala habitat patches that are close to or smaller than 50 ha, with the aim of increasing their size and improving connectivity. Lower priority should be given to revegetation of areas adjacent to very small (less than 2 ha in size) habitat patches. Restoration programs should

consider the shape of the area being revegetated and avoid constructing narrow linear patches.

6. It is likely that lower quality categories of koala habitat perform important buffering functions, as well as providing supplementary food and shelter resources and habitat connections. Hence the presence of lower quality habitat should not be disregarded when selecting locations for habitat corridors.

7. Emphasis should be placed on the need to **maintain ecological integrity** of protected habitat areas. Priority should be given to contiguous areas of preferred habitat, particularly those that are known to contain koalas. However, the apparent absence of koalas should not preclude the protection of such areas as koala populations may establish over time and such areas may be a critical resource for the recovery of local populations.

References

References

Anonymous. 1929. *The Queensland Naturalist* **7**:25.

Applied Biostatistics. 1996. *Biomstat*. Supporting software for Sokal, R. R., and Rohlf, F. J. 1995. Biometry (3rd Ed). W. H. Freeman and Company. New York.

Australian Koala Foundation. 1998. *Assessments of Impacts on Koalas Associated with the Proposed Subdivision 42-44 Raleigh Terrace, Currumbin Waters*. Unpublished Report to Witheriff Nyst Solicitors.

Australian Koala Foundation. 2004. *Koala Beach Koala Plan of Management*. Unpublished report to Ray Group Pty. Ltd.

Biolink. 2003. *Assessment of Core Koala Habitat within the Area 13 Urban Investigation Area*. Unpublished report to Hastings Council.

Biolink. 2004. *Kings Forest Draft Koala Plan of Management*. Unpublished report.

Biolink. 2005a. *An ecological overview of koalas and their habitat on the Innes Peninsula, Port Macquarie NSW*. Unpublished report.

Biolink. 2005b. *North Hawks Nest Draft Koala Plan of Management* Unpublished report to Crownland Developments.

Biolink. 2006. *Conserving Koalas in the Coomera – Pimpama Koala Habitat Area: a view to the future*. Unpublished report to Gold Coast City Council.

Campbell, P., Prentice, R. and McRae, P. 1979. Report on the 1977 koala survey. *Wildlife in Australia* **16**:2-6.

Dique, D. S., deVilliers, D. L. and Preece, H. J. 2003. Evaluation of line-transect sampling for estimating koala abundance in the Pine Rivers Shire, south-east Queensland. *Wildlife Research* **30**:127-133.

Ellis, W. A., Carrick, F., Lundgren, P., Veary, A. and Cohen, B. 1999. The use of faecal cuticle examination to determine the dietary composition of Koalas. *Australian Zoologist* **31**:127-133.

Ellis, W. A. H., Melzer, A., Carrick, F. N. and Hasegawa, M. 2002. Tree use, diet and home range of the koala (*Phascolarctos cinereus*) at Blair Athol, central Queensland. *Wildlife Research* **29:**303-311.

Environmental Protection Agency. 2006. *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016* Queensland Government - Environmental Protection Agency.

Faulks, J. 1990. A preliminary investigation of the distribution of koalas and their potential habitat in the Tweed Shire, and implications for management. *Australian Zoologist* **27(1 & 2):**1-13.

Gordon, G., Hrdina, F. and Patterson, R. 2006. Decline in the distribution of the koala *Phascolarctos cinereus* in Queensland. *Australian Zoologist* **33(3):**345-358.

Hasegawa, M. 1995. Habitat utilisation by koalas (*Phascolarctos cinereus*) at Point Halloran, Queensland. M.Sc. Thesis, The University of Queensland, Brisbane.

Hawkes, N. H. 1978. Identification and management of koala eucalypt trees in New South Wales. Pp. 89-96 in T. Bergin (Ed) *The Koala – Proceedings of the Taronga Symposium*. Zoological Parks Board of New South Wales, Sydney.

Hindell, M. A. and Lee, A. K. 1987. Habitat use and tree preferences of koalas in a mixed eucalypt forest. *Australian Wildlife Research* **14:**349-360.

Hindell. M. A., and Lee. A. K. 1990. Tree preferences of the koala. Pp. 117-121 in A. K. Lee, K. A. Handasyde and G. Sanson (Eds) *Biology of the Koala*. Surrey Beatty and Sons, Sydney.

Kikkawa, J. and Walter, M. 1968. Report on the koala survey, 1967. *Wildlife in Australia* **5:**100-103.

Kimura, M. and Crow, J. F. 1963. The measurement of effective population number. *Evolution* **17:**279-88.

Lacey, R. C., Borbat, M. and Pollak, J. P. 2006. *Vortex: A stochastic simulation of the extinction process*. Version 9.61. Chicago Zoological Society, Brookfield, Illinois.

Lee, A. K. and Martin, R. 1988. *The Koala – A Natural History*. University of NSW Press, Sydney, NSW.

Lehmkuhl, J. F. 1984. Determining size and dispersion of minimum viable populations for land management planning and species conseration. *Environmental Management* **8:**167-76.

Lunney, D., Phillips, S., Callaghan, J. and Coburn, D. 1998. A new approach to determining the distribution of koalas and conserving their habitat: a case study from Port Stephens Shire on the central coast of New South Wales. *Pacific Conservation Biology* **4:**186-196.

Lunney, D., A. Matthews, C. Moon, and S. Ferrier. 2000. Incorporating habitat mapping into practical koala conservation on private lands. *Conservation Biology* **14:**669-680.

Lunney, D., O'Neill, L., Matthews, A. and Sherwin, W. B. 2002. Modelling mammalian extinction and forecasting recovery: koalas at Iluka (NSW, Australia). *Biological Conservation* **106:**101-113.

Martin, R. and Handasyde, K. 1999. *The Koala: Natural History, Conservation and Management* (2nd ed). Australian Natural History Series, University of New South Wales Press, Sydney.

McAlpine, C. A., Callaghan, J. G., Lunney, D., Bowen, M. E., Rhodes, J. R., Mitchell, D. L., and Possingham, H. P. 2005. Conserving south-east Queensland koalas: how much habitat is enough? Pp 11-17 in G. L. Siepen and D. Jones, editors. *Proceedings of the 2005 south east Queensland biodiversity conference*. University of Queensland, Gatton Campus.

McAlpine, C. A., Rhodes, J. R., Callaghan, J., Bowen, M., Lunney, D., Mitchell, D., Pullar, D.and Possingham, H. P. 2006. The importance of forest area and configuration relative to local habitat factors for conserving forest mammals: A case study of koalas in Queensland, Australia. *Biological Conservation* **132:**153-165.

McAlpine, C. A., Rhodes, J. R., Callaghan, J., Lunney, D., Peterson, A., Mitchell, D., Curran, T., and Possingham, H. P. 2007. *Planning Guidelines for Koala Conservation and Recovery-a guide to best planning practice.* Prepared by the University of Queensland and the Australian Koala Foundation.

McLean, N. and Handasyde, K. A. 2006. Sexual maturity, factors affecting the breeding season and breeding in consecutive seasons in populations of overabundant Victorian koalas (*Phascolarctos cinereus*). *Australian Journal of Zoology* **56:**385-392.

Melzer, A. 1994. Aspects of the ecology of the koala, *Phascolarctos cinereus* (Goldfuss, 1817), in the sub-humid woodlands of central Queensland. PhD thesis, University of Queensland. Brisbane.

Melzer, A. and Lamb, D. 1996. Habitat utilisation by a central Queensland koala colony. Pp. 93-101 in G. Gordon (Ed.) *Koalas, Research for Management*. World Koala Research Incorporated, Brisbane.

Mitchell, P. 1990. The home ranges and social activity of koalas - a quantitative analysis. Pp. 177-187 in A. K. Lee, K. A. Handasyde, and G. D. Sanson (Eds) *Biology of the Koala.* Surrey Beatty and Sons, NSW.

Moore, B. D., Wallis, I. R., Marsh, K. J. and Foley, W. J. 2004. The role of nutrition in the conservation of marsupial folivores of eucalypt forests. Pp. 540-575 in D. Lunney (Ed.) *Conservation of Australia's Forest Fauna* (2nd ed). Royal Zoological Society of New South Wales, Mosman, NSW.

Patterson, R. 1996. The distribution of koalas in Queensland – 1986 to1989. Pp. 75-81 in G. Gordon (Ed.) *Koalas – Research for Management. Proceedings of the Brisbane Koala Symposium.* World Koala Research Incorporated, Corinda.

Penn, A. M., Sherwin, W. B., Gordon, G., Lunney, D., Melzer, A. and Lacy, R. C. 2000. Demographic forecasting in koala conservation. *Conservation Biology* **14(3):**629-638.

Phillips, B. 1990. *Koalas, the Little Australians We'd All Hate to Lose*. Australian Government Publishing Service, Canberra.

Phillips, S. and Callaghan, J. 1996. *Koala Habitat Atlas: Tweed Coast.* Prepared for Tweed Shire Council by the Australian Koala Foundation.

Phillips, S. 1999. *Habitat utilisation by the koala Phascolarctos cinereus – towards a new approach for effective conservation and management.* Ph.D. Thesis. School of Resource Science and Management, Southern Cross University, Lismore NSW.

Phillips, S., J. Callaghan, and Thompson, V. 2000. The tree species preferences of koalas (*Phascolarctos cinereus*) inhabiting forest and woodland communities on Quaternary deposits in the Port Stephens area, New South Wales. *Wildlife Research* **27:**1-10.

Phillips, S. and Callaghan, J. 2000. Tree species preferences of koalas (*Phascolarctos cinereus*) in the Campbelltown area south-west of Sydney, New South Wales. *Wildlife Research* **27:**509-516.

Phillips, S. 2000a. Population trends and the koala conservation debate. *Conservation Biology* **14(3):**650-659.

Phillips, S. 2000b. *Tree species preferences of the Koala* Phascolarctos cinereus *as a basis for the delineation of management areas for recovery planning in New South Wales*. Report to the NSW Koala Recovery Team.

Phillips, S. 2002. *An Assessment of koala (*Phascolarctos cinereus*) populations of the Kings Forest area in a regional context*. Report to NSW Department of Environment & Conservation.

Phillips, S., Hangar, J. and McKee, J. 2004. *A preliminary appraisal of the health and ecological status of koalas on Raymond Island, Victoria*. Report to Department of Sustainability and Environment on behalf of Steve Irwin Foundation.

Phillips, S. (submitted). Development of a lightweight, portable trap for capturing free-ranging koalas (*Phascolarctos cinereus*). *Australian Zoologist.*

Queensland Parks and Wildlife Service. 2002. *EK News* Vol 1 December 2002. EPA/QPWS.

Ryan, T. S., Bean, A. R., Hosking, B. B., Wilson, B. A. and McDonald, W. J. F. 2003. *Gold Coast City Council 1998 Nature Conservation Mapping Review Stage 1*. Report to Gold Coast City Council, produced by Queensland Herbarium, Environmental Protection Agency and Queensland Government.

Sattler, P. S. and Williams, R. D. (Eds) 1999. *The Conservation Status of Queensland's Bioregional Ecosystems*. Environmental Protection Agency, Brisbane.

Smith, A P. 2004. Koala conservation and habitat requirements in a timber production forest in north-east New South Wales. Pp 591-611 in D. Lunney (Ed.) *Conservation of Australia's Forest Fauna* (2nd ed). Royal Zoological Society of New South Wales, Mosman, NSW.

Strahan, R. (Ed.) 1995. *The Mammals of Australia*. Reed New Holland.

Sullivan, B. J., Norris, W. M. and Baxter, G. S. 2003. Low-density koala (*Phascolarctos cinereus*) populations in the mulgalands of south-west Queensland. II. Distribution and diet. *Wildlife Research* **30:**331-338.

White, N. A., and Kunst, N. D. 1990. Aspects of the ecology of the koala in southeastern Queensland. Pp 148-151 in A. K. Lee, K. A. Handasyde and G. D. Sanson (Eds) *Biology of the Koala*. Surrey Beatty and Sons, Sydney.