Comprehensive Koala Plan of Management

for

Eastern Portion of Kempsey Shire LGA



Volume II – Resource Study

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This report was jointly authored by Dr. Stephen Phillips and Ms. Marama Hopkins. A founding committee member of what is now the NSW Koala Preservation Society, and latterly an independent scientist with the NSW Koala Recovery Team, Stephen Phillips has over 35 years of experience with koalas and is an internationally acknowledged authority on the ecology, conservation and management of the species; he has spoken at national and international conferences and written popular articles, book chapters and scientific papers on koala conservation and management, the latter published in journals such as *Pacific Conservation Biology*, *Wildlife Research* and *Conservation Biology*.

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Maps

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Draft #	4	**Date**	**Signature**
Prepared by	Stephen Phillips Marama Hopkins	26th March 2009	
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Acronyms used in this report

Acronyms have little place in the spoken form of the English language. Nonetheless, their use in a document such as this can save both time and space. Below we provide a list of acronyms that have been used throughout this report, along with their associated 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; these pages are here in order to provide an easy reference point.

ANZECC: Australian and New Zealand Environment and Conservation Council

AoO: Area of Occupancy

ARP: Approved Recovery Plan (Recovery Plan for the Koala)

CKH: Core Koala Habitat

CKPoM: Comprehensive Koala Plan of Management

DA: Development Application

DECC: NSW Department of Environment and Climate Change

DoP: NSW Department of Planning

EoO: Extent of Occurrence

Ha: Hectares

IKPoM: Individual Koala Plan of Management

IUCN: International Union for the Conservation of Nature

KAG: Koala Advisory Group

KE: Kempsey East (study area)

KS: Kempsey South (study area)

KSC: Kempsey Shire Council

KSLGA: Kempsey Shire Local Government Area

LGA: Local Government Area

MCP: Minimum Convex Polygon

NSWKPS: New South Wales Koala Preservation Society

PFT: Primary Food Tree

PKFT: Preferred Koala Food Tree

PKH: Preferred Koala Habitat

RG-bSAT: Regularised Grid-based Spot Assessment Technique

SAT: Spot Assessment Technique

SEPP 44: *State Environmental Planning Policy No 44 (Koala Habitat Protection)*

SFT: Secondary Food Tree

Executive Summary

The Kempsey Shire Local Government Area (KSLGA) covers an area of approximately 3,381 km^2 extending along the coastline from the general vicinity of Point Plomer in the south to near Scotts Head in the north, and extending westwards to Werrikimbe and New England National Parks in elevated areas of the Great Dividing Range. The following document details the results of a koala habitat assessment, which forms the basis of the Comprehensive Koala Plan of Management (CKPoM) for the eastern portion of the KSLGA, an area of approximately 1,109 square kilometres, a project guided by State Environmental Planning Policy No 44 (Koala Habitat Protection).

Analyses of 303 historical records for the period 1949 – 2007 revealed that koalas were once more widespread throughout the study area than they are today. Records suggest that there has been a mean reduction of 22% in the range parameter *Extent of Occurrence*, but there was no evidence to indicate a significant decrease in the *Area of Occupancy* when data for the period 1949 – 1989 were compared to those of the last two decades. Evidence for generational persistence whereby koalas have been consistently recorded over periods of time that span at least 3 - 5 consecutive decades was most apparent in the south of the study area over a large area from Dondingalong through Kundabung and eastwards to Crescent Head. Historical records also identified two further localities: Eungai Rail and Stuart's Point – Grassy Head, but a lack of recent records, coupled with the results of field survey, create some uncertainty as to whether these populations are still extant. Recent records for the South West Rocks area, latterly supported by anecdotal evidence, and a spread of discontinuous records over a 20 year time frame in the Collombatti Creek area allude to the presence of two further areas of localised generational persistence.

Habitat sampling was undertaken systematically at two levels of resolution, the first at 2.5km intervals across the entire study area, the second at 350m intervals within two localised areas identified by the Koala Advisory Group.

Field sites were sampled using SAT methodology in order to gather data on occupancy, koala activity and food tree preferences, also supported by fixed radius and strip transect searches for koalas. At the macro-landscape scale, 66 field sites were sampled. Evidence of koalas was recorded at 23 field sites, 22 of which were located in a habitat block between Kempsey and the southern boundary of the study area. In conjunction with the 66 field sites approximately 53 hectares of habitat was searched for koalas but none were observed. Data from the macro-landscape sampling and that inferred by the historical record were strongly in accord with each other in terms of likely population attrition in the north. Of the two areas identified for more intensive sampling, sixteen sites were sampled at Kempsey East, five of which were active. Twenty eight sites were sampled at Kempsey South, 20 of which were active. Collectively, 8.6ha were collectively surveyed for koalas, but none were sighted. Regardless, modelling of metapopulation boundaries was strongly supported by independent koala sightings opportunistically by Council officers.

A further 50.3 ha were searched for koalas during ancillary spotlighting surveys within Maria National Park and Maria River State Forest. Again, no koalas were sighted during the course of these assessments.

The tree use data set was derived from the 23 active field sites associated with the macro-sampling, and the 25 active field sites associated with micro-sampling. Collectively, 2,906 trees comprising at least 17 species of *Eucalyptus* and at least 19 species of non-eucalypt were sampled. Analysis of tree use data confirmed Tallowwood *E. microcorys*, Grey Gum *E. propinqua*, Forest Red Gum *E. tereticornis*, Swamp Mahogany *E. robusta* and White Stringybark *E. globoidea* to be amongst the tree species most preferred by koalas in the study area. When these data were examined on the basis of aggregated soil landscape data, Tallowwood, Forest Red Gum and Swamp Mahogany were inferred to be amongst the most preferred food trees species on alluvial and transferral soil landscapes where, on the basis of other studies, they likely function as primary food tree species for koalas. In contrast, Tallowwood, Grey Gum and White Stringybark were the most preferred tree species on erosional and residual soil landscapes. Regression analysis of the Tallowwood data set indicated that preferential use of this particular species was strongly size-class related, thus inferring secondary food tree status; hence vegetation communities occurring on these low nutrient soil landscapes currently exhibit a low koala carrying capacity; these results highlighted the importance of the limited food resource represented by large individual Tallowwood trees within the study area.

Knowledge about tree preferences and the variable nutritional status of Tallowwood enabled a without prejudice classification of the available vegetation mapping layer in order to derive a map of preferred koala habitat for the study area, this being an aggregation of three different koala habitat categories (Primary, Secondary (Class A) and Secondary (Class B)), each of which offer differing carrying capacities for koalas. Primary koala habitat, predominantly in the form of forest communities dominated by either Swamp Mahogany and/or Forest Red Gum, is widely scattered in small patches with a total coverage of 1,190ha; Secondary (Class A) habitat wherein primary koala food trees are sub-dominant features of the community occupy approximately 23,064ha, while Secondary (Class B) habitat wherein secondary koala food trees are the major determinant of carrying capacity occupies 28,385ha. Approximately 69% (15,045ha) of the Secondary (Class A) habitat is represented by Paperbark dominated communities, the bulk of which does not contain preferred koala food trees. Hence this particular habitat category significantly over-estimates the amount of preferred koala habitat that is present in the study area. A minimum of 80% of existing koala records occurred within the three koala habitat categories that were modelled.

Collectively, all survey data suggests the presence of a mostly low-density koala population. While a population estimate remains elusive, our data suggests that it will be small, and likely in the vicinity of less than 600 animals in total, the majority of which occur in the south of the study area. Low density koala populations present novel management problems for consideration; individual animals are highly mobile, tree visitations are brief and a correspondingly greater time is spent on the ground travelling between suitable food trees. Such considerations mandate that retention of preferred food trees is of the highest priority and that management of the existing populations be proactive.

In order to place remaining koala populations on a more sustainable footing, the CKPoM proposes recognition of three Koala Management Areas within which maintenance of koala habitat values should be given the highest priority. Management objectives within these key areas focus on habitat retention, particularly Tallowwood and other preferred food trees, habitat restoration, information gathering and the amelioration of threatening processes currently operating within these areas, the objective being to halt and ultimately reverse the trend of population decline through informed and active management.

PART 1

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 utilise 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; Moore *et al*. 2005). However, within a given area only a few of the available *Eucalyptus* species will be <u>preferentially</u> browsed, while others, including some non-eucalypts, may be incorporated into the diet as supplementary browse or utilised for other purposes (Lee and Martin 1988; Hindell and Lee 1990; Phillips 1990; 1999; Phillips *et al.* 2000; Phillips and Callaghan 2000). There is increasing evidence that – even amongst preferred food tree species – their palatability to koalas can be significantly influenced by nutrient availability (Moore and Foley 2000; Phillips and Callaghan 2000).

Koalas do not have a high reproductive output; females reach sexual maturity between eighteen months and 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 (2000a) estimating a generation time 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 do 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 Noosa Shire indicated that the probability 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 habitat that were < 50 ha in size, while the chance of koala presence started to decline below a habitat patch size of around 150ha. Such issues are exacerbated in landscapes that are only capable of sustaining low-density koala populations wherein the home range requirements of individual animals in the population may exceed 100ha (Jurskis and Potter 1997; Ellis *et al*. 2002). At the population level, there is also the need to cater for population expansion and/or contraction over time, with large enough areas of habitat retained to enable optimal occupancy rates to be maintained (Phillips *et al*. submitted).

Historical perspective

It appears that prior to European settlement, the koala was a prominent feature of the fauna in the Macleay Valley, being described as 'abundant' and featuring in local indigenous law and legend, the most widely-known being the naming of Yarrahapinni after Yarra, the Dunghutti word for koala (Standing 1990).

Settlement of the area by Europeans commenced in the 1830s with the establishment of grazing and agriculture on the fertile river floodplains; this followed extensive timber removal which formed the basis for initial industry in the area (Standing 1990). It is these areas which would have historically provided some of the highest quality habitat for koala populations, being described as thickly timbered with cedar and eucalypts. Following clearing of the river valleys, pressure on the timber resource turned to the surrounding hills, and during the late 1800s hardwoods including Tallowwood *Eucalyptus microcorys* were extensively sourced from these areas. It is during this time period that reports of 'hundreds' of sick and dying koalas were made by local residents and that shooting of koalas was widespread for the fur trade, as evidenced in local historical record and newspaper advertisements calling for skins. These pressures combined appear to have been the catalyst for the decline in koala abundance, and continuing agriculture and timber harvest in areas of most valuable koala habitat provide little opportunity for populations to recover.

Despite the long history of koala populations in the region and apparent obvious decline in the local population, in contrast to the Port Macquarie-Hastings LGA to the south, and the Coffs Harbour LGA to the north, the Kemspey LGA has mostly escaped the scrutiny of contemporary koala researchers.

Threatening processes

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

- Destruction of koala habitat by ill-advised clearing for urban, rural-residential and associated 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.

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 New South Wales the koala is listed as 'Vulnerable' for purposes of the *Threatened Species Conservation Act 1995*, and as such is also the subject of a recently approved Recovery Plan (DECC 2008).

State Environmental Planning Policy No 44 (Koala Habitat Protection) came into effect in October 1995, seeking to halt the decline in koala numbers and to provide for koala population recovery. To assist this objective and amongst other things SEPP 44 promotes the preparation of a *Comprehensive Koala Plan of Management* (CKPoM) for all or part of each Local Government Area (LGA) listed in Schedule 1 of SEPP 44. A CKPoM offers a number of advantages when compared to an *Individual Koala Plan of Management* (IKPoM) by way of the following:

(i) A Development Application (DA) on land to which a CKPoM applies need not include an IKPoM provided the DA is consistent with the CKPoM,

(ii) a CKPoM facilitates a strategic and coordinated approach to the management of koalas and their habitat at an appropriate landscape scale,

(iii) a CKPoM reduces the resources required by Council to process individual DAs, and

(iv) a CKPoM facilitates government, non-government and community involvement with the process of koala conservation.

Despite the preceding benefits, few of the 106 LGAs listed in Schedule 1 of SEPP 44 actually have an approved CKPoM in place – often resulting in the requirement for large numbers of IKPoMs that are often poorly informed, and lack necessary overview at a scale that is of relevance to koalas.

Given the preceding circumstances, sustainable planning for koalas must 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 and/or restored. Within the context of the study area, the ability of SEPP 44 to achieve necessary conservation and management outcomes is generally limited to activities triggered by the need for a Development Application in accord with the requirements of Council's LEP. Rural lands, which otherwise comprise the bulk of land within the study area, are for the most part exempt from SEPP 44 with clearing and/or modification of habitat regulated by the *Native Vegetation Act 2003*.

Structure of this report

Including this introduction (Part 1), the koala habitat and population assessment herein comprises five parts – Part 2 details the results of analysis of historical koala records, while Part 3 details results obtained from the field work component and examines issues of habitat use and occupancy. Part 4 takes data from Part 3 and uses it to determine preferred koala food trees and subsequently categorise mapped vegetation communities from a koala's perspective in the context of preferred koala habitat and the associated ability of the landscape to support and/or sustain free-ranging koala populations. Part 5 essentially summarises the preceding results in the context of a longer-term management prognosis and planning framework for the study area.

The information that follows has been prepared in response to a project brief from Kempsey Shire Council, and in general accord with requirements specified by the Director-General of the NSW Department of Environment and Climate Change in accord with Regulation 12 of *State Environmental Planning Policy No 44 (Koala Habitat Protection)*.

The study area

The study area (Figure 1.1) being the focus of this CKPoM covers an area of 1,109km^2 (110,914ha), this equating to approximately one third of the total land area under governance of Kempsey Shire Council (KSC). Located on the mid north coast of New South Wales (NSW) within the North Coast Bioregion, the study area supports the greater proportion of the LGA's resident population of approximately 28,000 people. While funding limited the extent of the study area, the eastern portion of the KSLGA is also that area under most pressure from development. The area includes much of the Macleay River floodplain, extending along the coastline from south of Point Plomer to Grassy Head - Yarrahapinni in the north and to Dondingalong, Kempsey, Collombatti and Eungai Rail in the west, the boundary in this latter area one that was arbitrarily defined to again capture those areas facing pressure from development, but using natural boundaries such as the Macleay River, roads and existing land use zonings. With a varied pedology and an elevation range from sea level to over 300m above sea level, a diverse variety of vegetation communities and fauna habitats are represented, with recent vegetation mapping by Telfer and Kendall (2006) and GHD (2007) describing a mosaic of rainforest, coastal heathlands, estuarine and freshwater wetlands in addition to extensive areas of eucalypt forest and woodland.

PART 2

The Historical Record

Introduction

The analysis of historical flora and fauna records is increasingly being used to inform management and conservation decisions. The koala is an iconic Australian mammal with a high public and political profile; as such it has already been the focus of one national survey (Phillips 1990) while in NSW three statewide surveys have occurred (Gall 1978; Reed and Lunney 1990; Lunney unpub). Analyses of historical koala records have also been used to inform planning outcomes at the Local Government Area level (Lunney *et al.* 1998).

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

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

(ii) 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.

Methods

Koala records were obtained from Kempsey Shire Council's records and the NSW Wildlife Atlas database. 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 removed from the dataset.

The distributional parameters "*Extent of Occurrence*" (*EoO*) and "*Area of Occupancy*" (*AoO*) (Gaston and Lawton 1990; Gaston 1997) were used to quantify changes in the spatial and/or geographical distribution of koalas 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 koala records over time; this was followed by *EoO* determinations for each decade for which sufficient data was available. Examination of changes in the related *AoO* was determined by creating a 2.5km x 2.5km

(625ha) grid cell overlay within the historical *EoO*, then randomly sampling 50% of these cells and enumerating the number within which koala records were present. This process was repeated over 10 iterations for each time period examined and analysed using standard two-sample *t*-tests. The 625ha grid cell size was considered the minimum necessary to accommodate such considerations as spatial uncertainty (use of different mapping datums, observer error etc) in addition to possible duplicate sightings.

Derived from our earlier work in south-eastern Queensland (Phillips, Hopkins and Callaghan 2007), we also employed the concept of "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, thus indicating the likely presence of resident and/or source populations, this being a mirror image of existing IUCN criteria which otherwise places weight on the concept of perceived population declines over a similar time period (World Conservation Union Species Survival Commission 1994). For the purposes of this study, "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.

Results

Koala Records

Three hundred and thirty seven individual records were obtained, including 20 covering the period Jan - Nov 2008 that were provided during the course of this project by Nathan Hegerty (Kempsey Shire Council), Dr Vanessa Standing and Mr. Bernard Whitehead. Once corrected for the presence of duplicate sightings, 303 records remained for analysis. The distribution of koala records for the study area is presented in Figure 2.1.

Chronology of sightings

The earliest recorded koalas in the study area occur in the south of the study area. Two records for 1949 are present in the database, the first of which comes from Crescent Head, while the second located some 13km to the west/southwest in the vicinity of Kundabung.

The next records in the historical data do not appear until the 1960s. These are important because they are the first that generally allude to the presence of koalas in the north of the study area (i.e. Stuart's Point - Grassy Head, and Eungai Rail), while further confirming the persistence of populations to the south.

The period 1980 onwards sees the most significant increase in the number of records, this being a consequence of projects such as the National Koala Survey in 1986-87, Dr. Dan Lunney's Community Wildlife Survey in 2006, and local survey effort. The listing of the koala as a threatened species in NSW during the 1990s has no doubt worked to elevate the species' profile and so increase the reporting rate.

Over the last two decades, the records potentially reveal two further matters of interest. The first is of some concern, this being an apparent decline in the reporting rate for records in the north of the study area. The last reported record for the Eungai Rail area was in 1990, while that for Stuart's Point – Grassy Head was during 2004. At the other end of this spectrum, a small cluster of records (n = 5) from the South-west Rocks area over the period 1999 – 2007 alludes to the presence of a further and previously unreported population at this locality, although local knowledge suggests koalas have been known from this area since at least the 1970s (V. Standing pers. comm.).

Figure 2.2 illustrates the trend in the reporting of koala records over the period 1940 – 2008.

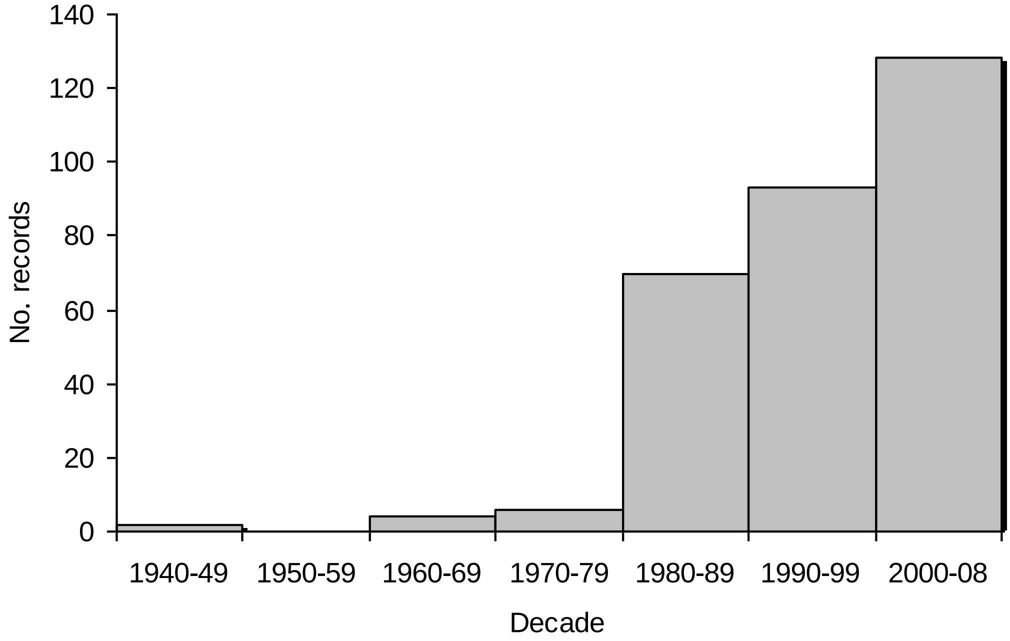

Figure 2.2. Chronological distribution of 303 koala records for the eastern portion of the Kempsey LGA over the period 1940 - 2007.

Extent of Occurrence

Available koala records for the study area reveal a historical *EoO* that approximates 114,150ha, this being the enclosed area captured by a MCP that by definition must necessarily include areas beyond the study area boundaries. 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 21.7% over the last seventy years when changes in MCP size for each of the last 3 decades are averaged and then compared to that obtained using all available records (Table 2.1). The reduction in *EoO* is most evident in the north of the study area and to a lesser extent in the southeastern corner (Figure 2.3).

Table 2.1 Percentage changes in the *Extent of Occurrence* of koalas in the eastern portion of the Kempsey LGA based on comparing the areas of Minimum Convex Polygons derived by connecting the outermost of all koala records collected over the period 1940 – 2007 with those obtained over the last three decades respectively.

Period	No. records	EoO (ha)	% change
1940 - 2007	303	114,150	-
1980 - 1989	70	75,577	- 33.8
1990 - 1999	93	92,131	- 19.3
2000 - 2007	128	100,457	- 12.0

Area of Occupancy

Changes in the *AoO* are much harder to quantify. As evidenced by Figure 2.2, over the period 1980 – 2008 there is clear increase in the probability of a koala record being present in any given grid cell, and hence it could be argued – and even demonstrated statistically - that there has also been an increase in the *AoO* during this time. However, such an argument remains singularly supported by the increase in the number of koala records for the period 1986 – 2007, a factor we have attributed to various matters detailed above.

Hence the question remained – given the extent to which the historical data is chronologically skewed, was 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 1940 – 1989 (n = 82) and 1990 onwards (n = 221). In order to deal with the disproportionately greater number of koala records for the period 1990 onwards, each of the iterations we undertook for this latter time period was based on 82 randomly selected records. This approach returned the following results:

1940 – 1989

Mean *AoO* estimated at 22.84 ± 2.63% (SD) of the study area.

1990 – present

Mean *AoO* estimated at 21.57 ± 2.49% (SD) of the study area.

Analysis of the data sets supporting these outcomes confirms that while there appears to have been a slight decrease in the extent of the study area being occupied by koalas since 1990, the difference when compared to that of the previous 50 years is not statistically significant (t = 1.01341, 18_{df}, $P > 0.05$).

Generational Persistence

Generational persistence was most evident in 3 localities within the study area, and inferred in 2 others, effectively capturing an area of approximately 38,750ha in total. A brief account detailing the location, approximate size and koala history of these areas is as follows:

a) Stuart's Point – Grassy Head

Koalas have been recorded from within an area of approximately 1,875ha over a period of 4 consecutive decades from 1969 through to 2004, the latter year being the last known record from this locality.

b) Eungai Rail

Koalas have been recorded from within an area of approximately 1,250ha over a period of at least 3 consecutive decades from 1964 through to 1990, the latter year being the last known record from this locality.

c) Dondingalong – Kempsey South – Kundabung – Maria River – Crescent Head

This is by far the largest area with chronologically continuous koala records, covering an area of approximately 27,500ha over a time period of at least 7 consecutive decades from 1949 through to the present day. A number of source populations are likely to be present in this area.

Disjunct records over a discontinuous 20 year period from 1988 to 2005 occur in the Collombatti Creek area, while more recent records plus anecdotal evidence (V. Standing pers. comm.) supports recognition of an additional area at South West Rocks. The locations and extent of those areas within which generational persistence is most evident are detailed in Figure 2.4.

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 303 records we have been able to quantify changes in the spatial/geographic range parameters of koalas over time, and identify areas supporting potentially important source populations.

An inherent problem associated with survey data such as historical records is that they are heavily 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 locations of source populations respectively. From this perspective, we have remained mindful that the first historical koala record for the study area *post* dates the clearing of vegetation on the Macleay River floodplain; based on vegetation remnants that remain, it was likely that much of this area not only supported koala habitat *per se*, but also resident koala populations.

It is with the preceding considerations and limitations in mind that the following key outcomes are expounded.

Key Outcomes

- The historical record indicates that koalas have a long history of occupation in the study area. The number of records available for analysis has increased substantively over the last 3 decades, a fact we attribute more to an increase in survey effort than any increase in koala distribution and abundance.

- Consideration of all historical records indicates that a reduction in the *Extent of Occurrence* of koalas within the study area of approximately 22% has occurred over the last 30 years. Range reduction has been most apparent in the north and south-eastern corners of the study area. Despite this trend however, there does not appear to be any statistically significant change in the associated *Area of Occupancy* over the last 20 years.

- Analysis of the historical record in terms of generational persistence revealed at least 5 areas of particular interest. The conservation status of two of these, Grassy Head – Stuart's Point, and Eungai Rail, appears tenuous given both the dearth of recent records and the results of macro-landscape sampling described elsewhere in this report. Conversely, a metapopulation likely comprising one or more source populations occurs in the south of the study area, with some evidence to suggest the presence of two further areas of generational persistence in the South West Rocks area and in the general vicinity of Collombatti Creek area to the immediate north of Kempsey.

PART 3

Field Sampling

Introduction

Analysis of historical and community-sourced koala records alone is unable to reflect the true distribution of koala populations within a given area. In order to best inform broad-scale koala population conservation and management, it is also important to determine the extent of koala population distribution across the planning landscape. Thus the integration of historical record analysis with contemporary data on distribution in order to identify likely habitat areas forms the basis for the focusing of management effort in order to best inform conservation and planning initiatives.

Standard approaches to addressing these issues on a landscape scale variously rely on extrapolation of localised survey data across large areas, broad-acre habitat modelling based on tree preference data, patch size and configuration, community reports and anthropogenic influence (e.g. Bryan 1997; Lunney *et al*. 1998; Gordon *et al*. 2006; McAlpine *et al*. 2006; Rhodes *et al*. 2006). At a local scale, a finer level of detail is required to unambiguously identify those areas of greatest importance to koala populations. Ideally though, the approach to providing such information at both levels of investigation should be unbiased and systematic and thus scientifically defendable (McKenzie and Royle 2005; Phillips *et al.* submitted)

We have applied Regularised, Grid-based Spot Assessment Technique (RG-bSAT) sampling throughout a number of areas in eastern Australia because of its proven ability to provide detailed information about koala population size, meta-population distribution and habitat use either at the macro-landscape scale or within a localised area (eg. Phillips *et al.* 2004; 2007; Phillips and Pereoglou 2005; Phillips and Hopkins 2007). It is this systematic yet efficient technique which formed the basis for field sampling throughout the CKPoM Study Area.

Field surveys were designed in order to address a number of objectives simultaneously. Specifically, the aims of the field survey component of the project were:

(i) to estimate the current extent and distribution of koala activity throughout the study area,

(ii) to investigate the extent, distribution and level of koala activity within the two focus areas identified by the KAG,

(iii) to obtain an estimate of population size, and

(iv) to obtain a representative tree-use data set for analysis of koala food tree preferences within the East Kempsey study area.

Methods

(i) Site selection

Aerial photography and the vegetation mapping of Telfer and Kendall (2006) and GHD (2007) was utilised for the purposes of selecting areas of vegetation to survey for koala activity. Vegetation mapping was filtered to remove all areas devoid of vegetation, non-woody vegetation and vegetation communities not containing eucalypts.

(ii) Macro-landscape sampling

In order to ensure a uniform and unbiased distribution of survey effort, a 2.5km x 2.5km regularised grid was overlain on the study area, the resulting grid-cell intersections used to determine the location of potential field sites where they were located within a mapped vegetation community containing eucalypts. Universal Transverse Mercator (UTM) coordinates for the location of these sites were uploaded into 12 parallel-channel Garmin GPS72 hand-held receivers navigating on the AGD66 datum. Although dated, 2005 aerial photography for the immediate area surrounding each grid-cell intersection was also inspected to determine the potential suitability of each site for sampling, ensuring sufficient vegetation existed for the application of the sampling protocol and conversely, ensuring that areas capable of supporting the protocol were not overlooked in cases where vegetation mapping had not recognised existing vegetation. In the field, a level of flexibility was allowed which enabled the repositioning of a site into an area determined as more suitable for sampling if this location was within 150m (5% of the sampling intensity) of the original site.

(iii) Micro-landscape sampling

In consultation with the KAG, two focus areas – Kempsey South (KS) and Kempsey East (KE) were identified for more intensive sampling, the purpose of such assessment being to provide insight into the status of koala populations in the two area areas while also demonstrating what we consider to be a "best practice" standard for koala habitat assessment in Kempsey. The two areas were selected on the basis of recent koala sightings in the vicinity, current/future development interest and/or a perceived importance to koala populations in the area.

The KS study area was located to the south of Kempsey's existing industrial area and was bounded partially by Burnt Bridge Rd, South St and West End Rd to encompass an area of approximately 340ha. The KE study area was bounded in part by Old Station Rd, Verges Creek Rd and Inches Rd and encompassed an area of approximately 300ha. The location and boundaries of both focus areas is provided in Figure 3.1.

In common with the macro-landscape sampling but at a different level of sampling intensity, vegetation mapping for the KS and KE study areas was overlain with a 350m x 350m grid (Figure 3.2). Again, field sites were located where grid-line intersections fell within vegetation communities containing eucalypts. Universal Transverse Mercator (UTM) coordinates for the location of sampling sites were uploaded into a 12 parallel-channel Garmin GPS72 hand-held receiver navigating on the AGD66 datum; 5% flexibility (i.e. 15-17m) was similarly allowed for in terms of final site selection in the field.

(iv) Assessment of habitat use

Once located in the field, each field site 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 of every tree within a 25m radius of the centre tree (0.196ha). At most sites where koala activity was encountered within a macro-landscape SAT site and an additional 17 inactive sites, a strip transect of approximately 1ha in area (usually 250m long and 40m wide) was also added to the assessment; the transect generally oriented along the contour with each tree in the transect surveyed for koalas by three personnel.

(v) Spotlighting

Towards the end of the fieldwork component, ancillary spotlighting transects were also carried out at selected locations within the study area. Transect sampling utilised a combination of walking and car-based spotlighting transects using a 100w handheld spotlight. Existing roads within national park and state forest estate were utilised for spotlighting transects, the aim being to augment the area-based density assessments detailed above and thus increase the probability of obtaining koala density data and an associated population estimate for the study area.

(vi) 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. For the KS and KE study areas, 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 interpolate koala activity patterns throughout each study area. This process ultimately produces an activity contour map which – based on the predetermined activity level thresholds of Phillips and Callaghan (submitted) – delineates important “source” areas supporting resident koala populations. Based on previous studies (Phillips and Forsman 2005; Phillips and Pereoglou 2005; Phillips *et al*. 2007), such modelling invariably encapsulates areas occupied by approximately 85% of contemporary koala records and 100% of observed breeding females, when independent observations of koalas are available for the study area. Thus, it is considered, and widely accepted that the areas identified as containing significant koala activity by the modelling process reflect the distribution of *core koala habitat* for the purposes of SEPP 44. It must be noted however, that boundaries modelled by the aforementioned process are indicative rather than definitive and potentially possess an outward measure of flexibility/tension that is commensurate with sampling intensity.

Results

(i) Macro-landscape sampling

Sampling was undertaken during August and September 2008. During macro-landscape scale sampling, a total of 1,737 trees from 66 SAT sites were assessed. A number of planned field sites were not sampled as a consequence of access difficulties due to terrain and/or the reluctance of some landholders to allow access onto private land.

Evidence of koala activity was recorded at 23 of the 66 sites within which koala activity levels ranged from 3.33% – 78.56% (Mean activity level: 22.16% ± 19.87%(SD)). This result also translates to an estimated occupancy rate/*AoO* of 34.84% ± 5.86%(SD) of sampled habitat (i.e. vegetation communities containing eucalypts). Koala activity was recorded from sites across private land, State Forest and National Park estate. Koala activity was strongly spatially auto-correlated (clustered) but recorded almost exclusively from sites in the south of the study area, activity in the north of the study area being limited to a single site located on freehold land to the west of the Pacific Highway at Barraganyatti (Figure 3.3). The obvious spatial auto-correlation gave us some confidence in terms of modelling the associated activity data such that, while a coarse representation, indicative *core koala habitat* boundaries for the study area could be determined (Figure 3.4). At this scale, potential key linkage areas are also readily apparent, being located outside of and between areas of significant activity. Approximately 44.3 hectares were intensively surveyed for koalas (12.9ha during radial searches at SAT sites and 31.4ha associated with transect searches) but no koalas were recorded.

(ii) Micro-landscape sampling

a) Kempsey East (Old Station Rd area)

Micro-landscape scale sampling was undertaken in September 2008, during which time a total of 16 SAT sites were sampled, 5 of which returned evidence of koala activity (i.e. faecal pellets recorded beneath at least one tree within the site) ranging from 3.85% – 55.5% (Mean activity level: 23.2% ± 19.24%(SD)). Splining and associated contour mapping consequently identified three small but relatively isolated cells of koala activity extending over vegetated, cleared and partially cleared areas with scattered trees including areas in close proximity to residences and farmland. Approximately 3ha were intensively surveyed for koalas but no animals were observed.

b) Kempsey South (Burnt Bridge locality)

A total of 28 SAT sites were sampled within the Kempsey South focus area, 20 of which returned evidence of koala activity ranging from 3.33% – 70.6% (Mean activity level: 15.2% ± 15.9%(SD)). With the exception of a small isolated cell in the north, modelling indicated that koala activity in the west and south of the study area was likely part of larger activity cells that extended beyond the study area boundary. A number of sites in the south of the study area were notably inactive, appearing to coincide with areas within which recent clearing activity had taken place. Approximately 5.5ha were intensively surveyed for koalas but no animals were observed.

Figures 3.5 and 3.6 illustrate modelled metapopulation (i.e. *core koala habitat*) boundaries within the KE and KS study areas, respectively. For the purpose of delineating these areas, we applied the threshold value of 9.47% based on the east coast, low population density activity model of Phillips and Callaghan (see discussion Part 4 and Appendix I).

Note: in the vicinity of the KS study area, three koala sightings were reported by KSC staff and contractors between August and September 2008, the locations of which are also detailed in Fig. 3.5. One of these records, that of a female with joey, falls within the boundaries defined by our metapopulation modelling, the other occurring approximately 350 metres to the west, immediately adjacent to but otherwise outside the study area.

Table 3.1 provides a summary of total survey effort accumulated through macro- and micro-landscape sampling components.

Table 3.1. Summary of effort undertaken during field sampling.

	Macro-sampling	Micro-sampling	
		Kempsey South	Kempsey East
SAT sites	66	28	16
Active sites	23	20	5
No. trees sampled	1,737	759	410
Area searched for koalas	44.3 ha	5.5 ha	3.1 ha

Spotlighting

Additional to that detailed above, a further 50ha of vehicle and/or foot based spotlighting transects were undertaken within the Maria National Park and Maria River State Forest over the period 08/08/08 – 27/10/08. These areas were selected because of the results obtained during the macro-landscape sampling phase of the project which confirmed occupancy by koalas in at least half of the areas surveyed. While koalas were heard calling at various localities during this ancillary fieldwork, again none were sighted. Table 3.2 provides a breakdown of survey effort.

Table 3.2. Summary of location, technique and survey effort undertaken during spotlighting surveys. MNP = Maria National Park; MRSF = Maria River State Forest * = koala heard calling in general vicinity but not observed.

Date	Locality	Tech.	~ Area surveyed (m)	ha
08/08/08	Eastern Trail MNP	foot	1,100m x 40m*	4.4
09/08/08	Northern Trail MNP	foot	1,500m x 20m	3.0
10/09/08	Cable Rd,MNP	foot	1,200m x 40m*	4.8
11/09/08	Needlebark Rd, MNP	foot	1,200m x 40m	4.8
12/09/08	MRSF	car	6,800m x 30m	20.4
27/10/08	Needlebark Rd, MNP	foot	1,300m x 40m*	5.2
27/10/08	Eastern Trail, MNP	foot	1,100m x 40m	4.4
27/10/08	Cable Rd,MNP	foot	800 x 40m	3.2
Total				**50.3**

These transect data infer a theoretical density of less than 0.02koalas/ha may apply over areas of similar habitat within southern parts of the East Kempsey study area. While crude and subject to qualifications inherent in such an approach, extrapolation of such data suggests a population size estimate of less than 600 koalas currently residing in the south of the study area ([no. active macro-landscape SAT sites = **46**] x [habitat grid cell size = 2500m x 2500m = **625**ha] x [**0.02**koala/ha]).

Discussion

Field surveys have confirmed that although koalas remain widely distributed in the study area, the majority of activity is concentrated in the south. The location of koala activity recorded during field sampling is strongly in accord with that inferred by analysis of historical koala records, specifically in terms of areas of generational persistence and perceived population attrition in the north of the study area. Koala distribution in the study area also distinctly coincides with large areas of contiguous forest (much of which is contained in National Park estate and State Forest) which are likely to currently (and historically) support the area's most significant source populations.

The estimated occupancy rate of approximately 35% is higher than that estimated through analysis of historical records. Given the qualifications inherent in the latter estimate of ~22%, the increase was not entirely unexpected but remains less than optimal. From a koala conservation perspective, an *optimal* occupancy rate is one which sees not all available habitat occupied, but one in which there is allowance for population expansion (into currently unoccupied areas) and population contraction (in response to eg, stochastic events). Indeed, as evidenced by situations in places such as French Is. (Vic) and Kangaroo Is. (SA), a population existing at 100% occupancy encounters stresses related to limited resource availability, a situation considered to be far from ideal. Results from our studies elsewhere [eg. Gold Coast, Qld (Phillips *et al.* 2007); Port Macquarie, NSW (Phillips and Forsman 2005)] of demographically stable, reproductive koala populations in good health consistently return occupancy rates approximating 50% of the available habitat (Phillips *et al*. submitted). Conversely, for populations considered endangered such as those in NSW's southeast forests, occupancy rates have been reported at as low as 8% (Allen and Phillips 2008). While for many this is a novel concept in terms of landscape-scale koala management, this notion makes ecological sense and infers the need for management to both recognise <u>and</u> make allowance for metapopulation contraction and expansion over time in response to ongoing recruitment and/or attrition events. This consideration highlights not just the need to remove and/or minimize known and potential threatening processes from those areas known to be currently occupied, but also to effectively buffer such areas from adverse impact, accommodate the need for population expansion, and ensure that effective habitat linkages are in place to facilitate ongoing recruitment processes.

Micro-landscape scale sampling using high resolution RG-bSAT has provided the detail required to confidently identify koala metapopulation boundaries, and thus *core koala habitat* in the KE and KS study areas, albeit with differing ecological outcomes for each. While it may not be immediately evident, it is also clear that the distribution of *core koala habitat* does not always coincide with what otherwise may be perceived as the best quality koala habitat. While counter-intuitive, in a management context this is an important outcome simply because it highlights the overriding social factors that otherwise govern the distribution of free-ranging koala populations.

This modelling also provides an indication of the likely conservation status of the population. Small, isolated cells such as those identified within the KE study area tend not to persist unless supported by a large source population in the vicinity. Given the relatively small size of the study area, it is possible that the cells we have identified are outliers of a larger population in the local area, however connectivity to an area of bushland large enough to support such a source population is limited, with the nearest source (for recruits) located 3 - 5km to the south west. Our results infer that no more than 2 - 3 koalas are currently ranging within the sampled area and suggests that the long-term viability of these cells is also limited.

In contrast to the above, the prognosis for animals in the KS study area appears better; population cells are larger, connectivity with likely sources of recruits is greater and regions of significant activity extend beyond the boundaries of the investigation area both to the south and west into areas of contiguous bushland. The absence of koala activity at a number of sites in the south of the study area coincides with areas recently disturbed by removal of vegetation (not visible in the available aerial photography). Although no sightings were recorded during field sampling and thus a population estimate is not possible for the area, activity patterns suggest that a minimum of 4 - 6 koalas may be ranging within the investigation area, and are likely part of a larger metapopulation cell. Recent koala records from within and adjacent to the study area also provide support for the assertion that the modelling of significant koala activity strongly coincides with those areas currently supporting resident koala populations.

Despite the cumulative effort of SAT sites, transect searches and spotlighting, the lack of koala sightings supports the assertion that the koala population in the East Kempsey study area currently exists at low density across the majority of its remaining distribution. There are two possible reasons for this, the first being that the population as a whole is dissolute and largely comprised of individual animals moving randomly across the landscape, the second being that the population is stable but at low density for other reasons. If the latter scenario is true, this suggests that the underlying ecology of the koala in the East Kempsey study area may be more similar to that of populations in areas such as Campbelltown and the forests of southeastern NSW (Phillips and Callaghan 2000, Phillips and Hopkins 2008) than in neighbouring Port Macquarie Hastings or nearby Coffs Harbour LGAs.

While investigation into the ecology of low density koala populations is ongoing and still in the relatively early stages, it is clear that the interactions of these populations with their habitat differ to that of higher density populations in terms of patterns of food tree utilisation and ranging behaviour. For example, due to issues of habitat quality (see Part 4) individuals are required to maintain larger home ranges than would otherwise be required in areas of higher quality habitat, thus larger areas of habitat are required to maintain these populations. Amongst other things, a consequence of the maintenance of a large home range, from an individual's perspective, is the requirement to make more frequent and larger movements on the ground between trees within its range, thus exposing the animal to a higher level of threat from processes such as vehicle collision and predation. In general, the influence of the full suite of threatening processes is exacerbated when in operation on populations occurring at sub-optimal occupancy rates and/or at low density.

Essentially, and importantly, the above considerations require that management of these populations makes allowances and provides for both the need to enable optimal occupancy rates to be maintained and to effectively minimise the effect of threatening processes on extant populations.

Key outcomes

- Distribution of koala activity is widespread throughout the East Kempsey study area but with the majority of activity largely confined to the south. Results are strongly in accord with trends inferred by analysis of the historical records, specifically with regard to population attrition in the north of the study area.

- The presence of koala faecal pellets in 23 of the 66 macro-landscape field sites translates to an estimated occupancy rate/Area of Occupancy of ~35% of all vegetation communities containing eucalypts. This estimate is considered to be less than optimal.

- Micro-landscape scale sampling in KE and KS demonstrated the utility of this approach for defining *core koala habitat* boundaries at a local scale. The koala population within the KS study area appears stable; likely supported by nearby source populations to the south and/or west. The KE population appears smaller and more fragmented with limited connectivity and questionable long-term survival prospects.

- A koala density estimate, and therefore an estimate of population size, remains somewhat elusive for the study area, our results inferring both low densities throughout the majority of the study area and a correspondingly small population estimate of probably less than 600 individuals overall. Management therefore needs to be sensitive to the heightened threatening processes associated with small and declining populations and provide for population expansion.

PART 4

Food trees & habitat mapping

Introduction

Koala habitat mapping provides an essential basis for understanding the distribution and abundance of koalas, for effective conservation planning and for priority setting. In order to define the quality of koala habitat it is important to have some understanding as to what elements of the vegetated landscape most influence regular use by koalas, and invariably these are the species' preferred food trees. The identification of preferred tree species across large and heterogenous landscapes however, is a complex process, as it is recognised that a number of factors influence the way koalas utilise this key suite of eucalypts, including the extent of fragmentation, historical disturbance, stochastic events such as fire, and the nutrient status of the soil (McAlpine *et al*. 2006, Phillips and Callaghan 2000, Moore and Foley 2000). This variability is also recognised in the ARP, which provides for identification of region-based lists of preferred koala food trees, whilst also requiring – in common with SEPP 44 – that food tree use by koalas be thoroughly investigated for a given region.

The ability to produce an ecologically accurate map of koala habitat is not only contingent upon an unambiguous identification of preferred food tree species as a means of categorising habitat in the first instance, but is subsequently dependent on the accuracy and detail provided by the associated vegetation mapping layer. Subject to such qualifications, the analyses described in this section provides the basis for understanding the utilisation of eucalypts by koalas throughout the study area, our objectives for this component of the study being to:

(i) identify preferred koala food trees for the East Kempsey study area, and

(ii) produce a map of preferred koala habitat.

Methods

The data set for this component of the study comprised tree use data from all macro- and micro-landscape scale SAT sites discussed in the previous section within which koala activity (i.e. presence of koala faecal pellets) was recorded.

(i) Identification of preferred koala food trees (PKFTs)

For a given tree species, the results from each 'active' field site were pooled to obtain a proportional index of utilization (the proportion of trees in the sample with one or more faecal pellets recorded beneath them) "*P*" – hereafter referred to as the 'strike rate'. Strike rate data was subsequently divided into primary and secondary data sets. For each tree species, criteria for inclusion in the primary data set required representation by a minimum sample size of 30 from at least 7 independent sites, and that n_iP_i and $n_i(1\text{-}P_i)$ were both at least as large as 5 (where n = sample size for tree species "*i*" and P = strike rate for tree species "*i*"). Thus the primary data set contains the most common tree species as well as those being most frequently utilised by koalas and therefore likely to be of some importance in sustaining the population. The extent of variation amongst strike rates within the primary data set was examined using log-likelihood ratios. Significant heterogeneity was addressed by a re-arrangement of tree species in order of decreasing strike rate for the purposes of conducting an unplanned test for homogeneity using simultaneous test procedures in order to statistically isolate the most preferred tree species.

Tree species allocated to the secondary data set were those that failed to meet one or more of the criteria outlined above, but were otherwise represented in a minimum of four independent sites. The extent of variation amongst strike rates within the secondary data set was examined using a Kruskall – Wallis ANOVA, with significant heterogeneity or unrelated trends addressed using a Mann-Whitney U test.

(ii) Influence of soil landscape of PKFTs

Use of certain tree species by koalas varies with soil type and thus it should not be assumed that tree preferences are uniform across a given landscape. For this reason, the tree use data set was also examined on the basis of two aggregated soil landscape categories - areas on erosional/residual soils and those arising from alluvial/transferral and associated soil landscapes. Stratification of sites by soil types was done using the soil landscape mapping of DLWC (2004a; 2004b).

(iii) Habitat categorisations

The vegetation mapping work of Telfer and Kendall (2006) and GHD (2007) served as the basis for koala habitat classifications. The two independently derived mapping layers were utilized without prejudice but with some difficulties due to differing mapping sources and techniques that were used in each instance. Information on vegetation community composition was obtained in the first instance from reports accompanying the respective mapping layers. Where further information was required, this was obtained from the corresponding forest type (FCNSW 1989) and/or CRAFTI (RCD 1997) mapping analogs, where such were specifically referenced.

Vegetation communities were categorised in accord with the definitions contained within the ARP as detailed below; such ecologically-based categorisations being considered to better reflect the extent of *potential koala habitat* for the purposes of SEPP 44 than that otherwise obtained using the 15% rule as defined in Clause 4 of SEPP 44. The terms “Primary”, “Secondary” and “Supplementary” food tree species are based on the mathematical models and associated definitions of Phillips (2000) and are consistent with terminology as used in the ARP.

Primary Habitat

Areas of forest and/or woodland wherein primary food tree species comprise the dominant or co-dominant (i.e. ≥ 50%) overstorey tree species Eg. Swamp Mahogany forest, Lowland Redgum forest.

Secondary (Class A) Habitat

Primary food tree species present but not dominant or co-dominant and usually (but not always) growing in association with one or more secondary food tree species. Eg. Dry Blackbutt forest.

Secondary (Class B) Habitat

Primary food tree species absent, habitat contains secondary and supplementary food tree species as components of overstorey. Eg. Scribbly Gum forest forest.

Other Habitat

Vegetation communities within which koala food trees are absent. Eg Rainforest, Sedgeland, Headland Brush Box forest.

Unknown

Areas for which insufficient information regarding community composition was available, and which require further investigation to determine habitat category.

In cases where there was deemed to be a moderate level of uncertainty or large variation in species composition within information accompanying vegetation mapping, habitat categories were assigned conservatively, erring on the side of higher koala habitat quality. Where a high level of uncertainty was recognized or an area had been excluded from vegetation mapping, it was assigned to the “unknown” category.

(iv) Validation of habitat mapping

Historical koala records detailed in Part 2 of this report were intersected with the habitat categorizations as determined above in order to gain some insight into the underlying ability of the resulting map of preferred koala habitat to reliably predict koala occurrence.

Results

(i) Koala Activity

Koala activity varied greatly across the landscape (mean activity/SAT site = 19.37% ± 18.20%(SD)). Koala activity on alluvial, transferral and estuarine soil landscapes was significantly higher when compared to that on erosional and residual soil landscapes (36.2% vs 16.50% respectively; t = 2. 8382, 46_{df}, $P < 0.01$).

(ii) Preferred koala food trees (PKFTs)

Data on 1,338 trees from 23 macro-landscape and 25 micro-landscape active SAT sites was potentially available for analyses. Tree species for which there was taxonomic uncertainty were excluded from the data set; this included the generic tree categories "stringybark" (n = 50) and "mahoganies" (n = 33), in addition to 10 individual *Eucalyptus* spp. which could not be positively identified in the field; this left 1,245 trees comprising 14 *Eucalyptus* spp. and 8 species of non-eucalypt for more detailed analyses.

Figure 4.1 illustrates the overall outcome arranged in terms of decreasing strike rates for eucalypt and non-eucalypt data sets respectively, without regard for statistical limitations imposed by sample size. *Eucalyptus microcorys*, *E. tereticornis*, *E. globoidea* and *E. propinqua* emerge as the most preferred eucalypt species. These trends are relative to their representation in active sites however, and the large variance associated with low sample sizes for most species requires that these data be further investigated through appropriate statistical techniques. Of the species represented below, 8 eucalypt and 5 non-eucalypt species returned sample sizes large enough to be included in the primary dataset (Table 4.1) for which strike rates pooled from all soil types ranged from 34% for *Eucalyptus microcorys* to 7% for *Allocasuarina littoralis*. *Eucalyptus microcorys*, *Corymbia intermedia* and *C. gummifera* were the most commonly sampled tree species.

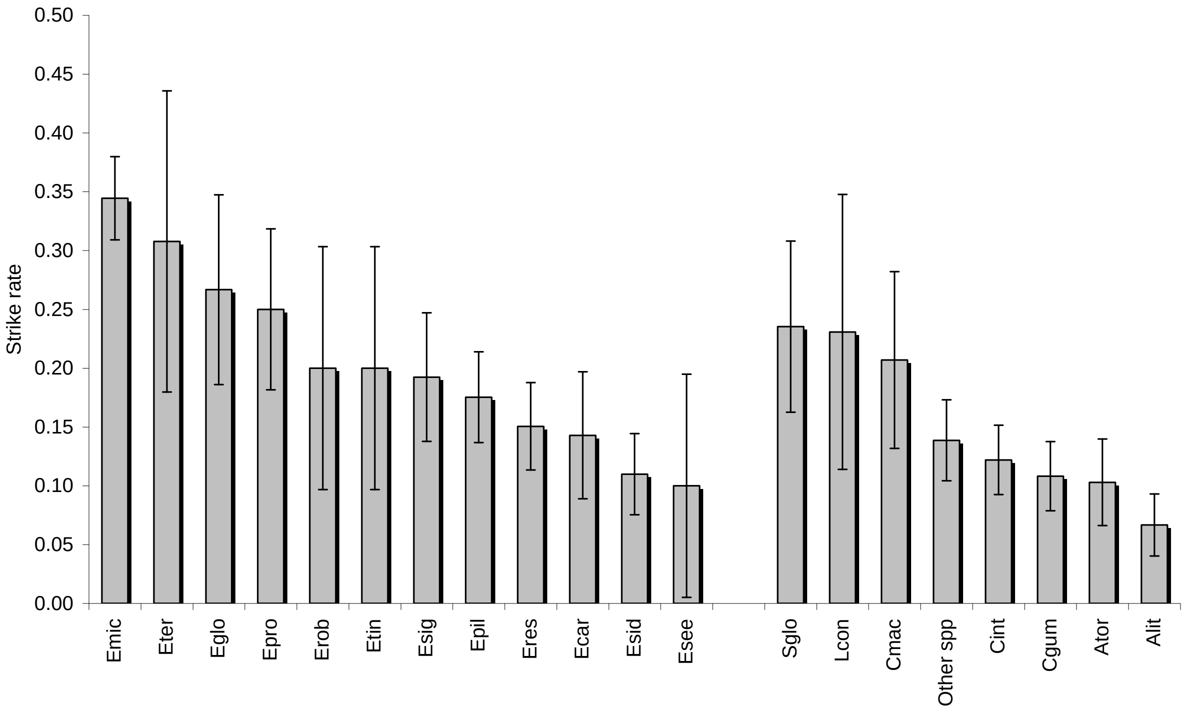

Figure 4.1 Summary of tree species utilisation at active SAT sites within the study area. Strike rates are presented as the proportion of each species recorded with faecal pellets, error bars represent standard error. "Other spp" category includes species from the Genera *Melaleuca*, *Casuarina*, *Allocasuarina*, *Acacia*, and rainforest species. Emic = *E. microcorys* (Tallowwood); Eter = *E. tereticornis* (Forest Red Gum); Eglo = *E. globoidea* (White Stringybark); Epro = *E. propinqua* (Grey Gum); Erob = *E. robusta* (Swamp Mahogany); Etin = *E. tindaliae*; Esig = *E. signata* (Scribbly Gum); Epil = *E. pilularis* (Blackbutt); Eres = *E. resinifera* (Red Mahogany); Ecar = *E. carnea* (Broad-leaved White Mahogany); Esid = *E. siderophloia* (Northern Grey Ironbark); Esee = *E. seeana* (Narrow-leaved Red Gum); Sglo = *Syncarpia glomulifera* (Turpentine); Lcon = *Lophostemon confertus* (Brush Box); Cmac = *Corymbia maculata* (Spotted Gum); Cint = *C. intermedia* (Pink Bloodwood); Cgum = *C. gummifera* (Red Bloodwood); Ator = *Allocasuarina torulosa* (Forest Oak); Alit = *A. littoralis* (Black She-oak).

For information and discussion purposes Table 4.2 provides a breakdown of tree species from sites within which no koala activity was recorded.

Table 4.1 Summary of tree species sampled from 48 active SAT sites within the study area. Number of trees sampled, SAT sites and overall strike rate ± SE are detailed for each of two aggregated soil landscape categories. Tree species are generally arranged in order of decreasing strike rate.

	Soil landscape					
	Residual/erosional			Alluvial/transferral/estuarine		
	Sites	n	P ± SE	Sites	n	P ± SE
Primary dataset						
Eucalypts						
E. microcorys	36	146	0.31 ± 0.04	4	34	0.50 ± 0.09
E. globoidea	11	30	0.27 ± 0.08			
E. propinqua	9	39	0.23 ± 0.07	1	1	1.00 ± 0.00
E. signata	9	51	0.18 ± 0.05	1	1	1.00 ± 0.00
E. resinifera	25	93	0.15 ± 0.04			
E. pilularis	17	78	0.13 ± 0.04	2	19	0.37 ± 0.11
E. carnea	12	41	0.12 ± 0.05	1	1	1.00 ± 0.00
E. siderophloia	23	82	0.11 ± 0.03			
Non-eucalypts						
Syncarpia glomulifera	8	33	0.21 ± 0.07	1	1	1.00 ± 0.00
Corymbia gummifera	18	111	0.11 ± 0.03			
C. intermedia	24	110	0.10 ± 0.03	2	13	0.31 ± 0.13
Allocasuarina torulosa	12	60	0.08 ± 0.04	2	8	0.25 ± 0.15
A. littoralis	17	88	0.06 ± 0.02	2	2	0.50 ± 0.35
Secondary dataset						
Eucalypts						
E. seeana	4	9	0.11 ± 0.10	1	1	0.00 ± 0.00
E. tindaliae	5	12	0.08 ± 0.08	1	3	0.67 ± 0.27
E. tereticornis	3	4	0.00 ± 0.00	2	9	0.44 ± 0.17
Non-eucalypts						
Lophostemon confertus	5	13	0.23 ± 0.12			
Corymbia maculata	6	29	0.21 ± 0.08			
Remaining trees						
E. acmenoides	2	5	0.00 ± 0.00			
E. grandis	1	1	0.00 ± 0.00	1	1	0.00 ± 0.00
E. robusta	1	1	0.00 ± 0.00	2	14	0.21 ± 0.11
Other spp	12	33	0.06 ± 0.04	4	68	0.18 ± 0.05
Total trees		**1069**			**176**	

"Other spp" category includes species from the Genera *Melaleuca*, *Casuarina*, *Allocasuarina*, *Acacia*, and rainforest species.

Table 4.2. Summary of tree species sampled from inactive SAT sites within the study area. Number of trees sampled and number of associated SAT sites are detailed for each of two aggregated soil landscape categories.

	Soil landscape			
	Residual/erosional		Alluvial/transferral/estuarine	
	Sites	n	Sites	n
Eucalypts				
E. microcorys	35	177	4	13
E. pilularis	22	122	7	43
E. resinifera	20	70	2	2
E. signata	10	70	3	13
E. siderophloia	20	68	2	6
E. carnea	16	67		
E. propinqua	17	58	2	11
E. robusta	2	23	6	28
E. seeana	6	14	1	1
E. globoidea	5	11	1	2
E. tindaliae	2	7	1	1
E. tereticornis	3	6	2	3
E. crebra	1	2		
E. grandis	1	1		
E. patentinervis			2	2
E. planchoniana			3	15
Other eucalypt	13	35	1	3
Non-eucalypts				
Allocasuarina torulosa	22	109	2	6
Corymbia intermedia	28	101	7	51
C. gummifera	15	62	1	2
Syncarpia glomulifera	8	40	2	14
A. littoralis	7	34	4	12
Melaleuca styphelioides	2	22		
Lophostemon confertus	10	18	2	8
Banksia integrifolia	1	12	2	13
C. maculata	2	11		
Casuarina glauca	1	10	4	36
M. quinquenervia	3	7	7	35
Other spp	13	58	7	33
Total trees		**1215**		**353**

"Other spp" category includes species from the Genera *Melaleuca, Callistemon*, *Exocarpus*, *Casuarina*, *Allocasuarina*, *Acacia*, and rainforest species.

a) Primary data set

There was significant heterogeneity in the pooled primary data set (G = 55.4281, 12_{df}, P < 0.001), with an unplanned test for homogeneity using simultaneous test procedures isolating *E. microcorys* as the most preferred tree species, while the suite of *C. intermedia*, *E. siderophloia*, *C. gummifera*, *A. torulosa* and *A. littoralis* were isolated as the least preferred (Table 4.3).

Table 4.3 The two homogenous data sets arising from the unplanned test for homogeneity using simultaneous test procedures (pooled data set).

Emic	*Eglo*	*Epro*	*Sglo*	*Esig*	*Epil*	*Eres*	*Ecar*	*Cint*	*Esid*	*Cgum*	*Ator*	*Alit*
━	━	━	━	━	━	━	━					
	━	━	━	━	━	━	━	━	━	━	━	━

Strike rates ranged from 31% for *E. microcorys* to 6% for *A. littoralis* within the primary data set for erosional and residual soil landscapes. Figure 4.2 illustrates the distribution of strike rates arranged in descending order for those species analysed. This data set also showed significant heterogeneity when analysed independently (G = 32.1283, 12_{df}, P < 0.01); again *E. microcorys* was isolated as the most preferred tree species (Table 4.4). The data sub-set for trees growing on alluvial, transferral and/or estuarine soil landscapes did not support similar analyses.

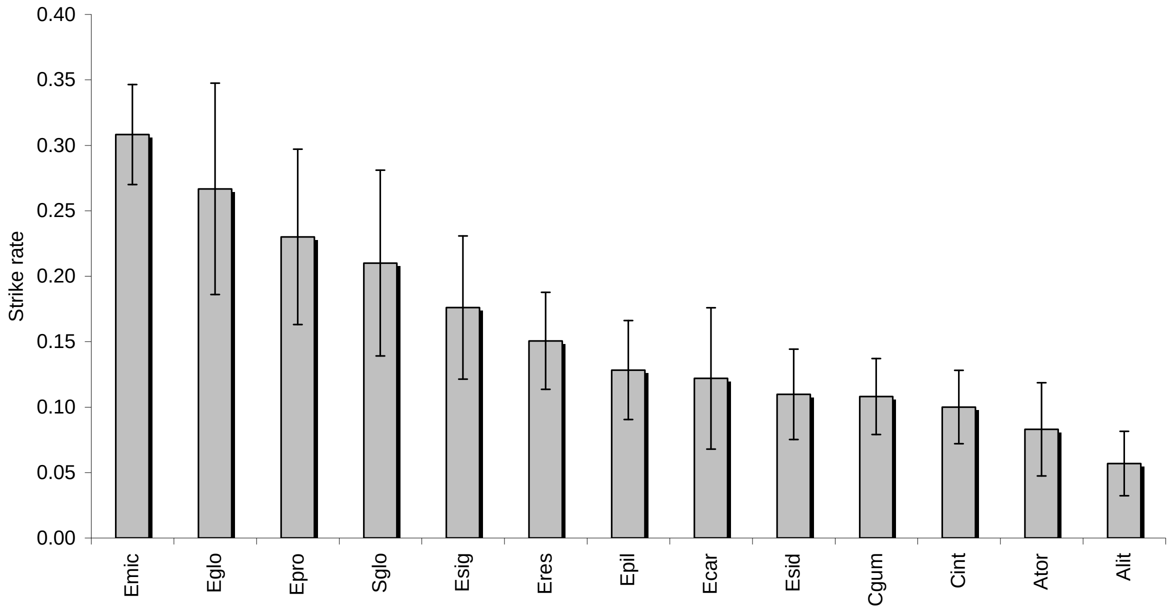

Figure 4.2 Summary of tree species utilisation at active SAT sites on erosional and residual soils within the study area. Strike rates are presented as the proportion of each species recorded with faecal pellets, error bars represent standard error.

Table 4.4 The two homogenous data sets arising from the unplanned test for homogeneity using simultaneous test procedures (erosional & residual soil landscape data set only).

Emic	*Eglo*	*Epro*	*Sglo*	*Esig*	*Epil*	*Eres*	*Ecar*	*Cint*	*Esid*	*Cgum*	*Ator*	*Alit*

Despite isolation as the most preferred tree species, on erosional and residual soil landscapes *E. microcorys* exhibited a strike rate that was significantly lower than that on alluvial, transferral and estuarine soil landscapes (G_{adj} = 4.250, 1_{df}, $P < 0.05$). This outcome mandated a more detailed investigation of the use of this species by koalas. Accordingly, the relationship between 50mm size class increments of *E. microcorys* (independent variable) and the associated strike rate for that size class (dependent variable) was examined using logistic regression. The resulting maximum-likelihood model revealed a significant positive association between size class and utilisation of *E. microcorys* (z = 2.154, 1_{df}, $P < 0.05$), with larger size classes showing higher proportional rates of utilisation than would otherwise be expected by chance (Fig 4.3).

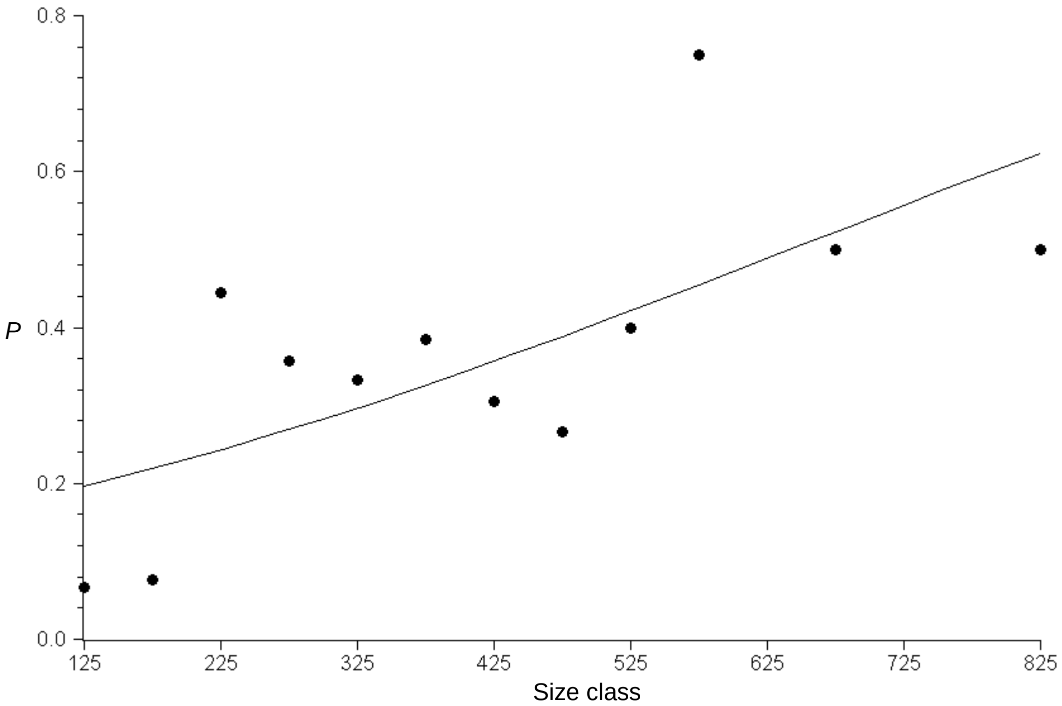

Figure 4.3 Complex logit model illustrating the relationship between *E. microcorys* size class and associated proportional levels of use by koalas on erosional and residual soil landscapes.

b) Secondary data set

Despite pooled strike rates within the secondary data set that ranged from 0.31 for *E. tereticornis* to 0.10 for *E. seeana*, no significant variation was evident (H = 2.554, 4df, P > 0.05), nor was the data set robust enough to allow any comparison between soil types. Inferentially, and in addition to that already established for *E. microcorys* through analysis of the primary data set, arguably predictable trends towards higher levels of use for *E. tereticornis* and *E. tindaliae* were apparent, as was the potential for *E. tereticornis* to be <u>less</u> preferred on erosional and residual soil landscapes (U = 6.0, P < 0.05).

c) Remaining tree species

Of the tree species that remained in the active site data set, only *E. robusta* indicated any trend towards high levels of utilization.

(iii) Habitat categorisations

The vegetation mapping of Telfer and Kendall (2006) and GHD (2007) collectively presented ~185 vegetation communities for consideration as koala habitat, the mapping capturing approximately 78,472ha of the study area within 5,042 individual polygons which varied in size from less than 0.5ha to 2,838ha (mean polygon size 17.30ha ± 78.51ha(SD)). Based on the tree use data set and associated analyses, supported by inferential trends apparent in the data, the following decision path formed the basis for habitat classification:

1. *Eucalyptus microcorys* was the most preferred tree species across the study area but exhibited differential use based on soil landscape. We thus regarded this species as a Primary Food Tree (PFT) on alluvial, transferral and estuarine soil landscapes, but as a Secondary Food Tree (SFT) on erosional and residual soil landscapes;
2. Based on inferential trends in the other data sets we assumed *E. tereticornis* and *E. robusta* to also be functioning as PFTs on alluvial, transferral and estuarine soil landscapes. With qualified statistical support the data also inferred that *E. tereticornis* was unlikely to be a PFT when growing on erosional and residual soil landscapes.
3. Based on associations and trends in all data sets we also assumed *E. propinqua*, *E. globoidea* and *E. tindaliae* to be amongst the suite of preferred trees.

Application of these determinations to vegetation communities comprising the vegetation mapping data layer in accord with the definitions adopted by this study resulted in approximately 52,640ha of preferred koala habitat being identified within the study area (Figure 4.4, Table 4.5). “Other” habitat comprised approximately 23,000ha, or 30% of the classified vegetation, while approximately 31,000ha of vegetation was unable to be classified at this stage.

Table 4.5 Mapped area in hectares for each category of classified habitat.

Habitat Quality	Area (ha)	% of total
Primary	1,190.44	1.57
Secondary A	23,064.05[1]	30.42
Secondary B	28,385.49	37.43
Other	23,188.94	30.58
Totals	**75,828.93**	**100 %**

Primary Koala Habitat

In the study area Primary Koala Habitat is limited to approximately 1,190ha of mapped vegetation, occurring as localised coastal lowland remnants of *E. robusta* and/or *E. tereticornis* ± *E. microcorys* dominated patches or linear strips on floodplains and along watercourses. As inferred by Table 4.6, the majority of this high carrying capacity habitat is currently unoccupied.

Secondary (Class A) Habitat

In the study area Secondary (Class A) Habitat comprises ~23,064ha of habitat otherwise restricted to communities containing *E. microcorys* and/or *E. tereticornis* and/or *E. robusta* on higher nutrient soil landscapes. The extent of this habitat within the study area is greatly overestimated however, the greater proportion (~69% or 14,970.65ha) being comprised of "Paperbark" dominated communities wherein preferred koala food trees are mostly absent or otherwise restricted to ecotonal areas.

Secondary (Class B) Habitat

In the study area Secondary (Class B) Habitat comprises the bulk of preferred koala habitat, encompassing ~28,385ha of habitat supporting *E. microcorys*, *E. propinqua*, *E. globoidea* and/or *E. tindaliae* growing on erosional and residual soil landscapes.

[1] Extent of total habitat area is significantly overestimated, refer to supporting text.

Other Habitat

Approximately 23,189ha of vegetation mapped as not containing eucalypts comprises the remainder of habitat that was able to be classified within the study area.

Unknown Habitat

A total of ~30,976ha of vegetation was unable to be classified due to a lack of information regarding floristic composition. The greater proportion of this category (96.6% or 29,911ha) comprised polygons classified as “cleared/partially cleared” bare ground” or which were excluded from classification during vegetation mapping. A cursory examination of these areas showed some lands with scattered vegetation which in many areas may qualify as koala habitat.

Excluding historical koala records occurring in “unknown” vegetation polygons (n = 39), and others associated with non-vegetated areas (n = 11), ~ 80% of those that remained (200 of 253) were collectively captured in the three koala habitat categories that were present (Table 4.6). Of those in the fourth category of “other”, the majority were located in close proximity to one or more of the three major habitat categories.

Table 4.6 Number of koala records associated with each of the koala habitat categories adopted for this study.

Habitat category	No. records	%
Primary	15	5.93
Secondary (Class A)	57	22.53
Secondary (Class B)	128	50.59
Other	53	20.94
Total	**253**	**100.00**

There remain a number of vegetation communities within both the “other” and “unknown” categories for which there was insufficient information on floristic composition to enable objective categorisation.

Discussion

Habitat assessment surveys for the study area have resulted in a useful dataset that assists resolution of the complex issue of habitat utilisation by koalas in the study area. The generally low activity levels however, have compromised the robustness of the data set in terms of its ability to unequivocally isolate the full suite of preferred food tree species. Regardless, there are sufficient inferences and trends to enable a measure of confidence in the outcomes that have been determined and to provide a sound basis for categorising habitat in terms of its importance to koalas in the study area. Given that ~80% of relevant historical koala records occurred within modelled areas of preferred koala habitat we also have confidence in this outcome.

With the exception of *E. robusta*, our data was generally successful in terms of identifying the most preferred tree species for koalas in the study area. *Eucalyptus robusta* 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 study area has reduced the occurrence of communities containing *E. robusta* to a number (n = 54) of small, disjunct patches totalling ~ 353 ha, much of which is now embedded in a disturbed urban/rural-residential landscape. It is therefore not surprising that koalas are absent and/or in decline in the immediate vicinity of remaining patches where *E. robusta* occurs, this statement evidenced by the generally low activity levels we recorded, and the high number of inactive sites that contained the species.

The results for *E. microcorys* were unexpected, this species generally acting as a primary food tree species for koalas throughout the greater part of its geographic range in eastern Australia. Indeed, this is the first study that we have undertaken where we have documented the phenomenon of size-class-based preferential selection for such a well known koala food tree, such intra-specific variation generally restricted to boxes, stringybarks and eucalypts in the *Symphomyrtus* sub-Genus (Phillips and Callaghan 2000; Phillips 2000b; Moore and Foley 2005). This knowledge is a highly significant outcome for the study area given that *E. microcorys* is the most abundant and widely distributed of the preferred food tree species; thus it is the distribution of this resource that will most influence the home range size of individual animals in the population.

Although not supported by a large data set, trends associated with the use of *E. microcorys* suggest that the species likely serves as a primary food tree on other soil landscapes, with habitat use by koalas in terms of mean activity levels (see Part 3) generally in accord with those reported for medium-high density populations. On low nutrient soil landscapes within the study area however, strike rates for *E. microcorys* were significantly lower, with patterns of utilisation indicating that the species acts as a secondary food tree in these areas. This in turn dictates a low koala carrying capacity for the associated landscape. Additionally, in areas where koalas were present, overall activity levels are also significantly lower (see Part 3), and comparable with those reported for other low density populations we have worked on (Phillips and Callaghan 2000; Phillips and Hopkins 2007). Implications for the determination of significant koala activity indicate thresholds which should be applied commensurate with the carrying capacity of the landscape, these being 22.52% for alluvial and associated landscapes and the lower 9.47% for erosional/residual landscapes (see Appendix I for derivation and discussion of activity level thresholds).

Key outcomes

- Trends in the tree use data set allude to a suite of tree species comprising Tallowwood (*E. microcorys)*, Grey Gum (*E. propinqua)*, Forest Red Gum (*E. tereticornis)*, Swamp Mahogany (*E. robusta)*, White Stringybark (*E. globoidea)* and another Stringybark (*E. tindaliae)* as the most preferred tree species for koalas in the study area. Koala activity associated with these tree species varied greatly across the landscape however, with significantly lower activity levels occurring on erosional and residual soil landscapes.

- Statistical analysis was able to isolate *E. microcorys* as the most preferred tree species across the study area. However, use of *E. microcorys* by koalas differed between soil landscapes, its pattern of utilisation on erosional and residual soil landscapes being both significantly lower and strongly size class dependent. There was also some evidence that *E. tereticornis* was unlikely to be a preferred tree species on erosional and residual soil landscapes.

- The combination of significantly lower koala activity levels on erosional and residual soil landscapes and the related size class dependent preferential utilisation of *E. microcorys* infer that vegetation communities on these soil types are only capable of supporting low density koala populations.

- A total of 52,640ha of preferred koala habitat can be identified based on available vegetation mapping. All three habitat categories recognised by the ARP are represented. Primary Koala Habitat is the least well represented and comprises less than 5% of the total area. The extent of Secondary (Class A) Habitat is likely to be overestimated by as much as 300%. Secondary (Class B) Habitat remains widespread and not only comprises the bulk of remaining koala habitat in the study area, but is also that on which the area’s remaining koala populations largely occur.

PART 5

Framework for Management

Preamble

The intent of this section is to integrate key outcomes arising from the preceding parts so as to place remaining koala populations inhabiting the study area into an appropriate ecological and planning context upon which necessary management responses can be developed. In terms of the latter, the approach we have taken is perhaps best described as that arising from the discipline of Conservation Biology's "declining population paradigm" by which the focus is one of identifying problems before they develop into crises and/or before populations disappear (Caughley and Gunn 1996). In this arena, the goals are centered on keeping remaining ecosystems intact, maintaining populations by preventing further declines, and addressing those mechanisms responsible for decline in the first instance. While it may seem a moot point, ultimately, tackling problems in this way is likely to be more effective (and less expensive), than the alternative, which is waiting until it is too late. We believe information detailed thus far has allowed insight into those factors which, from both a historical and modern day perspective, have had a negative impact on both habitat quality and the ability of free-ranging koala populations to maintain optimal population size and/or occupancy rates across the landscape, the majority of which continue to operate.

The theory and practical techniques for enacting the abovementioned philosophy and associated management response is already enshrined in the management plan concept advocated by the current approach to threatened species management promulgated by the *Threatened Species Conservation Act 1995*, the *Environment Protection and Biodiversity Conservation Act 1999*, statutory planning policies such as SEPP 44, and other recovery orientated legislation. To this end and amongst other things, SEPP 44 proposes that areas of identified *core koala habitat* be included in environmental protection zones, or otherwise have special provisions applied to control the development of that land. However, *core koala habitat* is a dynamic rather than static phenomenon, the boundaries of which can be expected to change over the course of successive koala "generations", the measure of which has been estimated to be 5.6 – 7.8 years (Phillips 2000). The direction of such change (i.e. expansion or contraction) is dependent upon several factors including:

a) The level of historical disturbance prior to assessment,
b) the size and proximity of any other resident population(s),
c) the availability of suitable habitat in proximity to that currently being occupied by resident koala populations,
d) habitat linkages to assist processes of emigration and recruitment, and
e) extant threatening processes.

Hence there can be problems enacting the relatively static concept of environmental protection zoning with a dynamic ecological phenomenon such as core koala habitat. Moreover, proposals to rezone large areas of otherwise zoned land to that of environmental protection can be expected to be met with a high level of resistance from landholders; nowhere has it been effectively enacted at a scale necessary to achieve effective koala conservation, and nor do we consider environmental protection zoning *per se* to be the panacea of koala conservation. Thus the approach taken herein has been to introduce the concept of Koala Management Areas (KMAs), these being cadastrally-based areas which currently and historically support the bulk of the koala population in the study area, herein defined by a 1,250m buffering of areas of generational persistence and intersecting the total area of generational persistence + buffer with the cadastre. Our intent in promoting this path has been twofold: (i) to provide a focus for koala management and conservation efforts, and (ii) encourage stewardship without unduly compromising other land use activities. It is within these areas that the working provisions detailed in Volume I of the plan are intended to provide koala populations the greatest level of protection in order to, as a minimum, ultimately, increase the carrying capacity of the landscape, facilitate an increase in population size to more sustainable levels and in so doing reverse what we perceive to be the primary factor influencing koala distribution and abundance in the study area. KMA boundaries are delineated in Map 2 which accompanies Volume I of the plan.

Ecological and planning context

a) Conservation status

Analysis of historical records and the ecological data obtained by fieldwork supports the notion that there has been a contraction in the *Extent of Occurrence* of koalas within the study area over time. While our subsequent analysis did not detect a significant decrease in the associated *Area of Occupancy*, we consider this latter result a false positive given such strong evidence of population attrition in the north, which if true would clearly return a significant decrease in the AoO should the question be asked again within the next decade. It is difficult to determine from the data whether or not populations in the north have become locally extinct, or whether they have been reduced to such low levels that localized extinction is imminent in the absence of assertive action.

While the estimate of the total number of koalas comprising remaining populations in the study area remains speculative, we suspect it lies somewhere below 600 animals, by far the greater proportion of which (perhaps as much as 95%) occupies habitat in the south of the study area and which must constitute a single metapopulation for management purposes. If nothing else, this mandates a precautionary approach until such time as the population size increases and/or information exists to the contrary. While there are a large number of unknown factors acting upon the viability of the study area's koala population, viability analyses for populations elsewhere often return poor prognoses even for large, apparently stable populations (Lunney *et al.* 2002; Phillips *et al.* 2007). Needless to say perhaps but such a small population size estimate is not reassuring, the number poised between that which would appear to offer some measure of independent long term population viability if appropriately managed, and that below which such longer-term population viability would be arguable. Hence there is no room for complacency.

With the bulk of the population contained in one area, it is highly vulnerable to impacts arising from a single stochastic event such as a major wildfire, the consequences of which might see population levels reduced to a sufficiently low number that long-term recovery potential would be severely compromised. Such a consideration mandates further effort to better understand the conservation status and viability of smaller, outlying populations in the north of the study area.

b) Habitat quality

The greater proportion of remaining koala habitat currently occupied by the study area's resident koala population(s) comprises small, localized areas of higher carrying capacity Secondary (Class A) habitat embedded in a disproportionately larger habitat matrix of Secondary (Class B) habitat, the latter growing on low nutrient substrates and currently only capable of supporting low-density koala populations. It is unknown whether the current low-carrying capacity exhibited on erosional and residual soil landscapes is an historical artifact that has manifested itself in response to the targeting by timber-harvesting operations of large size class, preferred food tree species such as Tallowwood and Grey Gum whereupon such trees have gradually become less common in the landscape. Regardless, it follows that an increase in the density and/or relative abundance of larger size class PKFTs across this landscape will also result in a higher carrying capacity for koalas over the long term.

c) Connectivity

Fundamental to the maintenance of koala (meta) population dynamics across the planning landscape is the issue of habitat connectivity. The dearth of data relating to the populations in the north of the study area makes any discussion regarding the need for habitat linkages hypothetical and baseless, save for the observation that in areas like the South West Rocks KMA, opportunities for establishing meaningful east-west links are heavily compromised by the existing development footprint.

Connectivity within the southern-most KMA currently occurs across a broad interface of predominantly rural lands, national park and forestry estate, the KMA effectively bisected by the Pacific Highway which contributes significantly to annual koala mortalities within the study area. Reducing the potential for road strike in this area, and hence improving connectivity via facilitating gene flow, should be one of the priority objectives of longer term koala management, the genesis of which should likely focus on the means by which riparian areas and associated bridge crossings on the Pacific Highway can be improved and/or modified to better facilitate and accommodate koala movements. Elsewhere in this KMA DECC's Key Habitats and Corridors mapping (Scotts 2003) also provides a conceptual framework for assisting connectivity by modelling potential corridors based on likely habitat associations. Moreover, within the Kempsey LGA generally, a number of such corridors have been modelled specifically with a view to providing connectivity for koala populations. Although provision of connectivity across the landscape is an essential component of koala management, the identification of theoretical corridors *per se* will not necessarily provide this outcome. Considered planning and management actions must also be implemented for their intent to be realized. To this end, the adoption of provisions for habitat retention and restoration across KMAs also provides for this connectivity, but on a broader, and potentially more effective, scale.

Threatening processes

i) *Fire*

Wildfire has the potential to exacerbate koala population decline (Starr 1990; Melzer et al. 2000) and indeed, may have already played a role in the decline and possible localized extinction of populations in the north of the study area where observations made during the course of the field assessment infer both high intensity and high frequency fire events over recent years. Wildfire has the potential to seriously compromise long-term population viability in the south of the study area.

<u>Appropriate management response</u>: Minimise potential for wildfire within key habitat areas and ensure rapid management response in event that such areas are threatened by fire; minimize use of fire for hazard reduction purposes within areas occupied by koalas.

ii) *Loss of preferred food trees*

Loss of preferred koala food trees represents a significant threat to remaining populations in areas which are already at low carrying capacity. The impact of such tree loss imposes nutritional stress on individual animals, and further reduces carrying capacity. The role of historical logging practices on current carrying capacity must remain speculative but is likely to have had some negative effect, especially given that at least two of the preferred food tree species, Tallowwood and Grey Gum, are also sought after for their timber. The *ad hoc* removal of preferred food trees in conjunction with clearing activities for urban, rural-residential, and other development related activities has a similar effect.

<u>Appropriate management response</u>: Ensure preferred food trees are effectively retained in areas currently occupied by koalas; maximize retention of preferred food trees in areas of preferred koala habitat; encourage use of preferred koala food trees in landscaping, bushland rehabilitation and/or regeneration programs.

iii) *Road strike*

Road strike is currently responsible for a number of ongoing koala deaths and is a major contributor to incidental koala mortality in the Kempsey area (Standing 1990). Available data points to that length of the Pacific Highway traversing the study area from the town of Kempsey southwards and to a lesser extent area along the Kempsey to Crescent Head Road, as potential black spots for koalas within the study area.

<u>Appropriate management response</u>: Council and RTA work to maximize provision of effective mitigation measures in known black spots; encourage greater driver awareness.

iv) *Climate change*

Increasing unreliability of rainfall along the eastern seaboard of Australia may mean that habitat currently being occupied in the south may become more marginal and current size class thresholds influencing preferential utilisation of preferred food tree species by koalas will increase as a consequence.

Appropriate management response: Continue to monitor tree use over time, maximize retention of large size class preferred food trees across landscape.

v) *Development for urban/rural residential purposes*

There are a number of examples in the study area where development for urban and/or rural residential purposes appears to have proceeded without due regard for the presence of koalas. Amongst possible reasons for this may be – as evidenced by the fieldwork we have undertaken – the generally low detection probability of both koalas and evidence thereof, the consequences of which may inadvertently lead assessments to conclude that areas are not important when in fact they are. Whatever the reason, there is a clear need for a more rigorous approach to the assessment of koala habitat within the study area, more so given the special management needs of low density koala populations.

Appropriate management response: Ensure that habitat assessment procedures are capable of detecting koala activity; ensure that information provided to KSC and other determining authorities is of a consistently high standard and interpreted appropriately; minimize impacts in areas being occupied by koalas.

vi) *Disease*

Diseases currently afflicting koalas include Chlamydiosis and a variety of immunological suppression disorders associated with endogenous Koala Retrovirus (KoRv). While the epidemiology of disease expression in koalas remains poorly understood, there is an established correlation with trauma and/or stress (Canfield 1987), with clinical expression historically manifesting itself greatest at the interface between developed landscapes and intact bushland areas.

Appropriate management response: Continue to monitor incidence of disease in study area's koala population, KAG to liaise with NSWKPS or nominated representatives.

Towards a more sustainable future

In the context of sustainable management koalas have relatively simple management needs. Within currently occupied areas it is fundamentally important that their suite of preferred food trees be retained. While for most people the loss of an occasional tree here or there may appear of little consequence, the implications for koalas can be considerable, more so given the low carrying capacity of the landscape and that individual animals comprising the remaining populations know exactly where such trees are located within the confines of their individual home range areas. Planning must also ensure that associated infrastructure needs do not impede use of the area, nor should it increase the potential for such things as motor vehicles and domestic dogs to pose undue threats to the longevity of either individual animals in the population, or the population as a whole.

If we are to manage populations effectively, we must also ensure adequate areas of unoccupied habitat are maintained which enable metapopulation dynamics and the underlying key processes of localized colonization and extinction events to continue across the landscape over appropriate ecological timeframes. Within areas of preferred koala habitat that are currently not being utilized, there is thus a similar need to ensure that the retention of preferred food trees is maximized, and that the potential for other factors that can impede successful colonization of such areas are taken into account.

The scale of habitat management required to effectively conserve a population such as that inhabiting the south of the study area should not be underestimated. To provide some indication of this the following is proffered: Accepting that habitat also exists beyond the southern boundary of the study area and that a minimum population size of at least 500 individuals is desirable if the population is to be guaranteed a measure of independent long-term population viability (Phillips *et al*. 2007), and assuming a average home range size of ~25 - 30ha while allowing for 50% occupancy rate to accommodate metapopulation dynamics (Phillips *et al.* submitted), a total habitat area of ~ 25,000 - 30,000ha would be required.

In a study such as this it is inevitable that issues and/or questions arise, the resolution of which will ultimately assist future management objectives. In order to further contribute to koala management in the eastern portion of the Kempsey Shire LGA and to direct future research effort during the life of the plan, a number of recommendations for further work within the study area are provided in working provisions within Volume I of the plan.

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APPENDIX I

The SAT Methodology

The *Spot Assessment Technique*: a tool for determining levels of localised habitat use by Koalas *Phascolarctos cinereus*.

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Summary

In order to more effectively conserve koalas, the National Koala Conservation Strategy promotes development of reliable approaches to the assessment of koala habitat. This paper describes a localised, tree-based sampling methodology that utilises the presence/absence of koala faecal pellets within a prescribed search area around the base of trees in order to derive a measure of koala activity. Confidence intervals associated with koala activity data from 405 randomly selected field plots within which koala faecal pellets were recorded have been utilised to assign threshold values for three population density/habitat biomes in eastern Australia. Subject to the need for a precautionary approach to data interpretation in areas that support naturally occurring, low-density koala populations, the approach is expected to assist field-based assessments by researchers, land managers and others interested in clarifying aspects of habitat utilisation by free-ranging koalas, especially where identification of important areas for protection and management is required.

Key-words. Spot Assessment Technique, Koala, *Phascolarctos cinereus*, SEPP 44, habitat assessment, survey techniques.

Introduction

The primary aim of the National Koala Conservation Strategy (NKCS) is to conserve Koalas (*Phascolarctos cinereus*) by retaining viable populations throughout their natural range (Australian and New Zealand Environment and Conservation Council (ANZECC) 1998). In order to develop a better understanding of the conservation biology of koalas, Objective three of the NKCS promotes the need for development of consistent and repeatable approaches to assessment of koala populations, in addition to the need for survey work to establish correlates of habitat quality at both broad geographic scales and the individual-tree scale within preferred habitats (ANZECC 1998).

The primary responsibility for conservation of free-ranging koalas and their habitat rests with State, Territory and Local Government authorities. In this regard State Government authorities in New South Wales and Queensland have enacted specific planning policies and/or strategic planning measures to assist koala conservation. However, the ability of these strategies to achieve their stated conservation objectives is hindered in part by the lack of standardised and reproducible methodologies that can be applied to the task of habitat assessment in the first instance.

In this paper we present a technique that we believe contributes to the need for a reliable approach to objectively assessing koala habitat use. An unreviewed progenitor to this work (Phillips and Callaghan 1995) was originally circulated to a limited audience following the Australian Koala Foundation's 1995 conference on the status of Koalas, its purpose at that time to promulgate an approach that could potentially assist field-based assessments by ecological consultants, land managers and others interested in quantifying aspects of habitat utilisation by free-ranging koalas. Much has happened since then such that the purpose of this work is to further refine the initial approach in the light of additional field studies and in so doing, formally supersede the earlier work.

Background to the approach

Traditionally, knowledge relating to habitat utilisation by free-ranging koalas has been reliant on opportunistic observations or radio-tracking data (Robbins and Russell 1978; Martin 1985; Hindell *et al*. 1985; Hindell and Lee 1987; 1988; White and Kunst 1990; Reed *et al*. 1990; Hasegawa 1995; Melzer and Lamb 1996; Pieters and Woodhall 1996). In other instances, emphasis has been placed on benign indicators such as accumulated faecal pellet counts (Moon 1990; Munks *et al*. 1996; Pahl 1996). However, both of the preceding approaches can be problematic. Firstly, existing models for determining tree preferences by free-ranging Koalas (Hindell *et al*. 1985) require a number of assumptions to be met which do not appear to hold in heterogeneous forest communities (Phillips 1999;

Ellis *et al.* 2002). Secondly, while accumulated faecal pellet counts can elucidate issues of koala abundance (Sullivan *et al*. 2002, 2004), they have proved of limited value when used to infer the importance of various tree species, (Munks *et al*. 1996; Pahl 1996). The ability to census and interpret faecal pellet deposits can also be influenced by other variables including visibility, tree morphometrics and insect activity (Achurch 1989; Melzer *et al*. 1994; Pahl 1996; Ellis *et al*. 1998; Sullivan *et al.* 2003). Scratch marks on trees are also an unreliable indicator of habitat use – they cannot be detected on some species whereas others retain them for long periods of time, nor is it always possible to confidently distinguish Koala scratches from those of other arboreal animals.

Studies of free-ranging koalas have established that those in stable breeding aggregations 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 density of preferentially utilised food tree species) and the sex of the animal (males tend to have larger home range areas than females). Long-term fidelity to the home range area is generally maintained by adult koalas in a stable population (Mitchell 1990; Phillips 1999, Kavanagh *et al*. 2007). An additional feature of home range use is the repeated use of certain trees, some of which may also be utilised by other koalas in the population (Faulks 1990; Mitchell 1990; Phillips 1999; Ellis *et al*. 2002).

Given the preceding considerations, it follows that areas being utilised by resident koala populations must also be characterised by a higher rate of faecal pellet deposition (see Lunney *et al.* 1998). For the purposes of this paper, we propose the term "areas of major activity" to describe such localities, regarding them as synonymous with the term "*Core Koala Habitat*" as defined by the NSW Government's *State Environmental Planning Policy No. 44 (Koala Habitat Protection)*, in addition to being a fundamental element of "Koala Habitat Areas" as defined by the Nature Conservation (Koala) Conservation Plan 2006 and

Management Program 2006 – 2016 (Environment Protection Agency/Queensland National Parks and Wildlife Service 2006).

The Spot Assessment Technique

The Spot Assessment Technique (SAT) is an abbreviated form of a methodology developed by the Australian Koala Foundation for purposes of the Koala Habitat Atlas project (Sharp and Phillips 1997; Phillips *et al*. 2000; Phillips and Callaghan 2000). This approach is probability-based and utilises a binary variable (presence/absence of faecal pellets within a prescribed search area around the base of trees) to determine tree species preferences, along with a commensurate measure of koala "activity" (number of trees with faecal pellets present divided by total number of trees in the plot) within a 40m x 40m (1600m^2) plot. Given that the selection of Atlas field plots is based on replication and stratification by soil landscape and vegetation associations in the first instance, the data presented for the purposes of this paper reflects a random selection of field sites within which koala faecal pellets were recorded. The SAT approach arose from observations of consistency within the four smaller (20m x 20m) sub-quadrats that otherwise comprise Atlas field plots and the consequent realisation that a smaller plot size would essentially provide the same empirical outcomes in terms of both tree species/faecal pellet associations and koala activity. However, the number of trees sampled in a smaller site is critical to any meaningful estimate of activity hence we have adopted the latter as the more important variable for the purposes of this technique.

Table 1 details results from Atlas plots that have been undertaken across a variety of habitat types and landscapes utilised by koalas in eastern Australia. To this end, while significant differences between mean activity levels from low and medium - high density Koala populations of the eastern seaboard are believed to reflect real differences in habitat quality and thus koala density (Table 1 - Southeast Forests/Campbelltown *vs* Port Stephens/Noosa: Levene's test: $F = 0.086$, $P > 0.05$; $t = -7.877$, $P < 0.001$), we submit that similar differences between medium - high density populations of the eastern seaboard and those from more western areas (areas generally receiving less than 600mm of rainfall annually) (Port Stephens/Noosa vs Pilliga/Walgett – Levene's test: $F = 0.925$, $P > 0.05$; $t = -4.743$, $P < 0.001$), more likely reflect differences in faecal pellet longevity as a consequence of aridity than they do habitat quality *per se*.

The SAT involves an assessment of koala "activity" within the immediate area surrounding a tree of any species that is known to have been utilised by a koala, or otherwise considered to be of some importance for koala conservation and/or habitat assessment purposes. In order of decreasing priority, selection of the centre tree for a SAT site should be based on one or more of the following criteria:-

1. a tree of <u>any species</u> beneath which one or more koala faecal pellets have been observed; and/or

2. a tree in which a koala has been observed; and/or

3. any other tree known or considered to be potentially important for koalas, or of interest for other assessment purposes.

In order to establish a meaningful confidence interval for the activity level of a given SAT site, a <u>minimum</u> of thirty (30) trees must be sampled. For assessment purposes, a tree is defined as "*a live woody stem of any plant species (excepting palms, cycads, tree ferns and grass trees) which has a diameter at breast height (dbh) of 100mm or greater*" (Phillips *et al*. 2000). In the case of multi-stemmed trees, at least one of the live stems must have a diameter at breast height over bark (dbhob) of 100 millimetres or greater.

Applying the SAT

1. Locate and uniquely mark with flagging tape a tree (the centre tree) that meets one or more of the abovementioned selection criteria;
2. differentially flag the 29 nearest trees to that identified in Step 1,

3. undertake a search for koala faecal pellets beneath each of the marked trees based on a cursory inspection of the undisturbed ground surface within 100 centimetres[1] from the base of each tree, followed (if no faecal pellets are initially detected) by a more thorough inspection involving disturbance of the leaf litter and ground cover within the prescribed search area.

An average of approximately two person minutes per tree should be dedicated to the faecal pellet search. In practice, more time will be spent searching beneath larger trees than smaller trees. For assessment purposes, the search should be concluded once a single koala faecal pellet has been detected or when the maximum search time has expired, whichever happens first. This process should be repeated until each of the 30 trees in the site has been assessed. Where the location of faecal pellets falls within overlapping search areas due to two or more trees growing in close proximity to each other, both should be positively scored for pellet(s). For more detailed reporting purposes, information relating to the site's location (UTM co-ordinates or Lat/Long), selection criteria, tree species assessed (and their dbh), and the radial area searched (as measured by distance from the centre tree) should also be recorded. Faecal pellets should not be removed from the site unless some verification (i.e. that they are in fact koala faecal pellets) is necessary.

Calculation and interpretation of Koala activity levels

The activity level for a SAT site is simply expressed as the percentage equivalent of the proportion of surveyed trees within the site that had a koala faecal pellet recorded within the prescribed search area. For example, given a sample of 30 trees, 12 of which had one or more faecal pellets recorded – the resulting activity level would be determined as 12/30 = 0.4 = 40 per cent.

[1] The minimum distance within which (on average) 50% of the total number of koala faecal pellets beneath the canopy of a given tree will be located (Jones 1994).

From the data sets presented in Table 1, we propose use of mean activity levels ± 99 per cent confidence intervals to define the limits of “normal” koala activity. Based on the threshold values that result we can then recognise three categories of koala activity as detailed in Table 2. Subject to qualifications regarding the need for a precautionary approach to low activity levels in some instances (see below), where the results of a SAT site returns an activity level within the low use range, we suggest that the current level of use by koalas is likely to be transitory. Conversely, where a given SAT site returns an activity level within the prescribed range for medium (normal) to high use - the level of use is indicative of more sedentary ranging patterns and is thus within an area of major koala activity.

A precautionary approach to activity levels in low use areas.

Ideally, SAT site activity levels should only be interpreted in the context of location-specific habitat utilisation data (e.g. Lunney *et al*. 1998; Phillips *et al.* 2000; Phillips and Callaghan 2000). Low activity levels recorded in what might otherwise be considered important koala habitat may be a result of contemporary koala population dynamics, landscape configuration and/or historical disturbances including logging, mining, fire frequency, agricultural activities and urban development. Such considerations should not necessarily detract from the potential importance of such habitat for longer-term koala conservation, particularly if koala food trees are present and koalas are known to occur in the general area. Application of a "Koala Habitat Atlas" type methodology over the larger area in conjunction with an understanding of ecological history (e.g. Knott *et al.* 1998; Seabrook et al 2003) would be useful to clarify such issues.

Low activity levels can also be associated with low-density koala populations. Stable, low-density koala populations occur naturally in some areas (Melzer and Lamb 1994; Jurskis and Potter 1997; Phillips and Callaghan 2000; Ellis *et al*. 2002; Sullivan *et al.* 2006). Koala density in such areas generally reflects the absence of “primary” food tree species and reliance by the population on “secondary” food tree species only (Phillips and Callaghan 2000; Phillips 2000).

While secondary food tree species will return significantly higher levels of utilisation when compared to other *Eucalyptus* spp. in the area, their level of use (as determined by field survey) will generally tend to be both size-class and/or density dependent when compared to a primary food tree species (Phillips and Callaghan 2000; Phillips 2000; Moore and Foley 2005). Because the autecology of koalas occupying habitat areas that do not naturally support one or more "primary" food tree species remains poorly understood at this point in time, we propose a precautionary approach whereby the presence of any activity in areas occupied by naturally occurring, low density populations should be regarded as ecologically meaningful for conservation and management purposes.

Recommended Applications

The SAT can be used in conjunction with land-use planning activities and/or policies that require koalas and their habitat to be assessed, especially where identification of important areas for protection and management is required. The technique is also suitable for monitoring purposes and can also be used as the basis for systematic, stratified, random or targeted surveys. However, the design and detail of sampling protocols that could be developed using the SAT approach are beyond the scope of this paper. Further information and advice regarding application and use of the SAT, interpretation of activity levels, and its application to the task of determining broad-scale tree species preferences, can be supplied if required. The authors would also be thankful for any feedback regarding application of SAT methodology for any of the purposes indicated in this paper.

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Table 1. Mean activity levels and related measures of central tendency (expressed as percentage equivalents) associated with habitat utilisation by Koalas from six areas in eastern Australia. Data relates to sites within which koala faecal pellets were recorded and has been pooled to reflect three major categories of Koala activity which correspond to low and med-high density Koala populations of the tablelands and areas east of the Great Dividing Range, and those of more western areas respectively. Koala densities for the east coast, low density category are arbitrarily defined at ≤ 0.01 Koalas/ha. (Data sources: [1]South-east Forests Conservation Council, unpub. data; [2]Phillips and Callaghan 1997; [3]Phillips and Callaghan 2000; [4]Phillips *et al*. 1996; [5]Phillips *et al*. 2000; [6]AKF, unpub.data; [7]Phillips 1999; [8]AKF unpub. data; [9]AKF unpub. data).

Area	Pop. Density	No. sites	No. trees	A/level	SD	SE	99% CL
East Coast							
S/E Forests[1]	Low	111	2979	11.85	6.84	0.65	1.70
Campbell town[2, 3]	Low	20	1194	6.52	4.72	1.06	3.02
Pooled		**131**	**4173**	**11.03**	**6.82**	**0.60**	**1.56**
East Coast							
Port Stephens[4, 5]	Med - high	76	3847	23.65	23.63	2.71	7.16
Noosa[6]	Med - high	63	1647	32.55	22.05	2.78	7.38
Pooled		**139**	**5494**	**27.68**	**23.27**	**1.97**	**5.16**
Western Plains							
Pilliga[7, 8]	Med - high	98	3656	42.52	22.78	2.30	6.05
Walgett[9]	Med - high	37	990	38.01	27.66	4.55	12.37
Pooled		**135**	**4646**	**41.28**	**24.19**	**2.08**	**5.44**

Table 2. Segregation of Koala activity into Low, Medium (normal) and High use categories based on use of mean activity level ± 99 per cent confidence intervals (nearest percentage equivalents) from each of the three area/population density categories indicated in Table 1.

Activity category	Low use	Medium (normal) use	High use
Area (density)			
East Coast (low)	< 9.47%	≥ 9.47% but ≤ 12.59%	> 12.59%
East Coast (med – high)	< 22.52%	≥ 22.52% but ≤ 32.84%	> 32.84%
Western Plains (med – high)	< 35.84%	≥ 35.84% but ≤ 46.72%	> 46.72%

FIGURES