Tweed Coast Koala Habitat Study

Report to Tweed Shire Council

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Table of Contents

Executive Summary

The Tweed Local Government Area (TLGA) covers an area of approximately 103,000ha extending from the Queensland border in the north to near the villages of Burringbar and Mooball in the south, and encapsulated to the west and south east by the Border, Nightcap and Burringbar Ranges. This report describes the results of a koala habitat and population assessment for the coastal portion of the TLGA, an area of approximately 21,200ha comprising lands surrounding Terranora and Cobaki Broadwaters in the north before extending along the coast for approximately 35km south of Tweed Heads generally between the coast and the Pacific Highway.

Analyses of 1,119 records of koala sightings over the period 1949-2009 revealed that koalas were once more widespread throughout the TLGA than they are today. Across the TLGA historical records infer a contraction of approximately 18% in the *Extent of Occurrence* over the last three koala generations, while *Area of Occupancy* rates appear to be unchanged at approximately 44%, a trend also mirrored within the Tweed Coast Study Area (TCSA).

Detailed koala population assessments in the TCSA involved application of a systematic sampling strategy primarily reliant on Spot Assessment Technique (SAT) methodology to gather data on koala presence and absence, food tree preferences, koala density and activity. Collectively, 134 field sites were sampled comprising 85 primary and 49 supplementary field sites, the latter focused around areas of significant koala activity. Evidence of habitat use by koalas was recorded in 17 of the 85 primary sites to provide a current estimated *Extent of Occurrence* of 12,631ha, with a current *Area of Occupancy* of approximately 20%.

North of the Tweed River, koala activity data indicates the persistence of small relic populations in the Terranora-Bilambil Heights and Tweed Heads South areas, however the short to medium-term viability of these populations is considered low in the absence of recruitment and is further reduced by the escalation of threatening processes arising from ongoing development. South of the Tweed River, three disjunct sub-populations occupy discrete areas of habitat between Bogangar and Pottsville. The presence of an additional small population outlier in the vicinity of Duranbah and Eviron Road is also indicated, the viability of which is clearly contingent upon recruitment from the aforementioned sub-populations to the east.

Evidence of generational persistence is widespread throughout the TCSA, testifying to a long history of occupancy and successful reproduction by koalas. Until now, the Tweed Coast's koala population has persisted in an increasingly patchy habitat matrix that is compartmentalised by road barriers and cleared lands, where it is subjected to the full suite of threatening processes. Comparison of historical record analysis and results of field survey suggests that occupancy by koalas within the TCSA has halved in recent years, with density data inferring a population estimate of approximately 144 koalas remaining in areas of currently occupied habitat. This population estimate infers that the population size of the TCSA koalas may already be below the minimum viable population size required to sustain long-term population survival. Fire frequency and intensity within remaining habitat areas over the last decade has been identified as the major contributor to recent population attrition, with recovery potential now impeded in remaining habitat areas by ongoing incidental mortality rates due mostly to motor vehicle strike.

Data from 2,734 trees collected during the course of the study were augmented by that from other studies in order to better investigate issues associated with utilisation of preferred koala food trees. Collectively, a total of 8,413 trees comprised the tree use data set. Consistent with previous work, four species – Forest Red Gum *Eucalyptus tereticornis*, Swamp Mahogany *E. robusta*, Tallowwood *E. microcorys* and Grey Gum *E. propinqua* – were identified as the most preferred species within the TCSA. Forest Red Gum and Swamp Mahogany were confirmed as primary food tree species, while size-class based variation in use of Tallowwood and Grey Gum confirmed a role as secondary food trees when growing on low-nutrient soils. Knowledge of tree preferences and the influence of soil landscape facilitated development of a four-tiered, hierarchical koala habitat classification decision-tree which resulted in approximately 3,815ha of potential koala habitat in habitat classes Primary, Secondary (A) and Secondary (B) being identified within the TCSA.

Koala habitat within the TCSA has undergone extensive fragmentation such that the large areas of *Eucalyptus* dominated forest and/or woodland necessary to enable a sufficiently large and viable koala metapopulation to survive are now restricted to a relatively small area between Bogangar and Pottsville; it is in this area that koala recovery and associated management actions must be focused. A number of mechanisms by which this can be achieved form the basis of conclusions and associated recommendations arising from the report, including recognition of cadastrally-based Koala Management Areas, stringent development controls, standardised ecological assessments, habitat restoration/rehabilitation works, fire and an *a priori* need to assertively deal with the issue of incidental koala mortalities; if these latter two matters cannot be dealt with expeditiously, assertively and in a meaningful way, the Tweed Coast koalas will be lost.

Acronyms used in this report

Note: Acronyms really 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 is a list of acronyms that have been used throughout this report, along with their associated expansions. We have endeavoured to precede our first use of a given acronym with its appropriate meaning but may have inadvertently omitted to do this in a few places along the way; this page is here in order to provide an easy reference point.

AoO: Area of Occupancy
ARP: Approved Recovery Plan
EoO: Extent of Occurrence
GPA: Generational Persistence Analysis
Ha: Hectare
IUCN: International Union for the Conservation of Nature
LGA: Local Government Area
MVP: Minimum Viable Population
NKS: National Koala Survey
NRMMC: Natural Resource Management Ministerial Council
PKFT: Preferred Koala Food Tree
PKH: Potential Koala Habitat
PVA: Population Viability Analysis.
SAT: Spot Assessment Technique
SEPP: State Environmental Planning Policy
TCKAG: Tweed Coast Koala Advisory Group
TCSA: Tweed Coast Study Area
TLGA: Tweed Local Government Area

Part 1

Introduction

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 and Van Dyck 2008). Throughout this range, koalas have been reported as utilising a diverse range of *Eucalyptus* species (Hawkes 1978; Lee and Martin 1988; Hindell and Lee 1990; Phillips 1990; White and Kunst 1990; Melzer and Lamb 1996; Lunney et al. 1998). Within a given area however, only a few of the available *Eucalyptus* species will be preferentially browsed, while others, including some non-eucalypts, may be incorporated into the diet as supplementary browse or utilised for other purposes (Lee and Martin 1988; Hindell and Lee 1990; Phillips 1990; Phillips 1999; Phillips et al. 2000, Phillips and Callaghan 2000).

Koalas are not a highly fecund species; females reach sexual maturity between eighteen months to two years of age and can theoretically produce one offspring each year. However, data indicates 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; Phillips (2000a) estimated a generation time for the species of 6.02 ± 1.93 (SD) years.

While the socio-biology of koalas is a critical aspect of their management, it remains an issue that tends to be 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 trees) and the sex of the animal (males have larger home range areas than do females). Long-term fidelity to the home range area is generally maintained by adult koalas in a stable population (Mitchell 1990; Phillips 1999); the dissolution of such social structure has been identified as a possible 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 is a primary consideration in terms of developing conservation and management strategies for free-ranging koala populations.

Habitat fragmentation can also be a contributing factor to population decline and/or dissolution. Recent research by McAlpine et al. (2005; 2006; 2007) into the landscape ecology requirements of koalas suggests that the chances 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 some evidence of critical patch size requirements for koalas, with koalas more likely to be absent from patches of primary and secondary habitat that were less than 50ha in size, while the probability of koala presence started to decline below a habitat patch size of around 150ha (McAlpine et al. 2007).

Conservation status of koalas within the TCSA has been of concern for some time. With a focus on the Terranora – Bilambil Heights – Tweed Heads South area Summerville (1990) presented an overview of problems facing the species in the Tweed Shire. Faulks (1990) collated and analysed local koala records for the TLGA and provided a number of recommendations. A Koala Habitat Atlas for the TCSA, along with recommendations for future management was also prepared for Tweed Shire Council by the Australian Koala Foundation (Phillips and Callaghan 1996).

Threatening processes

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

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

The majority of these processes occur in the TCSA.

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 (NRMMC 2009). In NSW, the Koala is listed as Vulnerable for purposes of the *Threatened Species Conservation Act 1995* (TSC Act). This listing initiated the preparation of a Koala Recovery Plan which was approved by the Minister for Climate Change and the Environment in November, 2008. The NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) also provides for the creation of State Environmental Planning Polices (SEPPs). Operating within this legislative framework, SEPP 44 (Koala Habitat Protection) encourages the conservation and management of naturally vegetated areas across the state which provide suitable koala habitat, with the stated objective of reversing the current trend of (koala) population decline. SEPP 44 aims to achieve this by:

a) requiring the preparation of plans of management before development consent can be granted in relation to areas of *core koala habitat*;
b) encouraging the identification of areas of *core koala habitat*; and
c) encouraging the inclusion of areas of *core koala habitat* in environment protection zones.

For the purpose of SEPP 44 *core koala habitat* is defined as (NB underlining is author's emphasis):

" *.. an area of land with a resident population of koalas, evidenced by attributes such as breeding females (that is, females with young) and recent sightings of and historical records of a population*."

A nomination to have the koala listed for purposes of the Commonwealth Government's *Environmental Protection and Biodiversity Conservation Act 1999* is currently being considered by the Minister.

Given the preceding legislative context, sustainable planning for koalas should endeavour to minimise the potential for adverse impacts in known koala habitat by ensuring that adequate areas of suitable habitat, and linkages to assist ongoing processes of recruitment and dispersal, are maintained or restored.

The study area

The Tweed Local Government Area (TLGA) covers an area of approximately 103,000ha within a zone of overlap between two major biogeographical regions, the

Torresian of tropical northern and north-east Australia, and the Bassian of temperate, south-east Australia. This zone encompasses an area of land from Lamington National Park in south-east Queensland to Barrington Tops in NSW and is defined by Burbidge (1960) as the Macleay-McPherson Overlap. With an elevation range from sea level to over 1,000m above sea level, a diverse variety of vegetation communities and fauna habitats are represented in the TLGA; including cool-temperate, sub-tropical and littoral rainforests, coastal heathlands and wetlands, along with substantial areas of eucalypt forest and woodlands. There are at least 50 distinct vegetation communities within the TLGA, many of which are depleted, inadequately conserved and/or listed as Endangered Ecological Communities for purposes of the TSC Act. It is estimated that the region supports Australia's highest concentration of threatened plant species, including 55 species endemic to the TLGA. Vertebrate fauna recorded in the region includes 105 species (17 Endangered and 88 Vulnerable species) listed under the TSC Act.

Over the past 150 years, over 44% of the original vegetation cover within the TLGA has been cleared or heavily disturbed (Kingston et al. 2004). Clearing on the coastal lowlands has been particularly extensive leaving only fragmented remnants on the steeper slopes. Most clearing has concentrated on the areas of low to moderate slope with higher rainfall and fertile soil (Kingston et al. 2004).

Tweed Shire is the fastest growing area on the far north coast and one of the fastest in the State. The Australian Bureau of Statistics 2006 census indicated 82,955 residents living in the area and forecast the population will exceed 120,000 by 2025. The vast majority of this growth is expected to occur along the coastal strip (i.e. Cobaki, Bilambil Heights, South Tweed Heads, Kingscliff to Bogangar and Pottsville), and it is this area that is the focus of this study; an area of approximately 21,200ha hereafter referred to as the Tweed Coast Study Area (TCSA), encompassing lands surrounding the Terranora and Cobaki Broadwaters and thereafter extending along the coast for approximately 35km south of Tweed Heads generally east of the Pacific Highway (Figure 1.1).

This report details the results of a project undertaken on behalf of Tweed Shire Council that has the primary aims of:

1. survey and analysis of current (and past) koala distribution, population size and dynamics;

2. analysis of preferred koala food trees;
3. delineation of vegetation considered to be *potential* and *core koala habitat*;
4. mapping and assessment of key threats to koalas and their habitat;
5. investigation of regional and local corridors;
6. assessment of areas suitable for habitat restoration and revegetation; and
7. assessment of local population viability.

It is intended that the preceding information will inform preparation of a Comprehensive Koala Plan of Management for the TCSA.

Structure of this report

Following this introduction (Part 1), the assessment that follows is comprised of five parts: Part 2 provides outcomes arising from analysis of historical and contemporary koala records for both the TLGA and the TCSA, including estimates of key range parameters, generational persistence and likely areas of high road mortality. Part 3 details field survey methodology utilised for the study, and the resulting outcomes in terms of estimating the current range and occupancy rate of koalas in the TCSA, the current distribution and extent of habitat occupied by resident koala populations, and population size. Part 4 examines at koala food tree preferences and associated influences of soil landscape before using the outcomes to construct a map of potential koala habitat for the TCSA. Part 5 presents a brief discussion of threatening processes operating on the Tweed Coast and provides the background for discussion on their mitigation. Part 6 discusses the outcomes from each of the preceding sections, examining related issues such as population viability and offers a prognosis for the future of koala populations on the Tweed Coast. Part 6 concludes with a series of recommendations intended to inform the next stage of the overall process towards drafting a Comprehensive Koala Plan of Management for the TCSA.

Part 2

The historical record

Introduction

Analyses of historical flora and fauna records are 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 been the focus of one national survey (Phillips 1990) while at least three statewide surveys have also occurred (Gall 1978; Reed and Lunney 1990; Lunney unpub. data). Analyses of historical koala records have also been used to inform planning outcomes at the Local Government Area level (Lunney et al. 1998; Phillips et al. 2007; Phillips and Hopkins 2008).

For databases which invite the public to contribute (eg. DECCW's Wildlife Atlas, WildNet) and that are publicly available, the requirement to report species records coupled with good record keeping by carer groups have resulted in increased reporting rates such that relatively large data sets are now available for use. However, inconsistency in reporting rates over time, and the *ad-hoc* nature of data collection and reporting, indirectly results in a suite of statistical issues which makes analysis of such data problematical, thus mandating that results be interpreted cautiously.

In this section we undertake an analysis of historical koala records for the TLGA and the TCSA with a view to examining the following issues:

(i) identifying broad changes/trends in the 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 and areas associated with koala mortalities due to motor vehicles.

Methods

Koala records were obtained from the NSW Wildlife Atlas database, Friends of the Koala's (FoK) koala database, Tweed Shire Council's community survey of 1998 and the Koala Rescue Unit (records up to 1994). Once collated, records were sorted chronologically by koala generation (determined to approximate six years) (Phillips 2000a) dating backwards from 2009, and then checked individually for replication. Multiple records for the same location within a given generation were removed.

In most cases we partitioned the resulting data set in order to undertake comparisons *pre* and *post* 1992 (the timeframes 1992-97, 1998-2003 and 2004-09 approximating the time intervals for the most recent three koala generations). This was done in order to place results in the context of International Union for Conservation of Nature (IUCN) criteria which place weight on the concept of perceived population declines over a time period of three generations (WCUSSC 1994). The large number of records available to this study enabled analyses to be extended to include separate assessment of these parameters across the TLGA as well as the subset of records attributable to the TCSA.

The range parameters "*Extent of Occurrence*" (*EoO*) and "*Area of Occupancy*" (*AoO*) are two key measures of the spatial distribution of a species, *EoO* being that area within the outermost limits of the area within which the species occurs. *Area of Occupancy* is the actual area within the *EoO* over which the species is found (Gaston 1997). The *AoO* is typically determined by enumerating the number of occupied grid cells and therefore is sensitive to sampling parameters such as sampling area and grid cell size. We chose to utilise both measures when attempting to quantify changes in the geographical distribution of koalas over time due to the ability of each to demonstrate differing features of distribution.

Extent of Occurrence

The historical *EoO* was determined as the total area 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 koala generation for which sufficient data was available. For both the TLGA and the TCSA, the area encompassed by the historical *EoO* was compared to the average individual *EoO* for the most recent three koala generations. For the TCSA, *EoO* assessments included a concave area to the west of the Pacific Highway, however as this factor was constant in all calculations it had no influence on comparisons.

The significantly lower number of records for the koala generation spanning the years 1998-2003 exerted an inequitable influence on calculations of changes in *EoO* over the last three generations. To counter this shortfall in the data, and because the location of these data points were completely encompassed by MCPs for the preceding and subsequent generations, we adopted the assumption that a koala record being present at a particular location during both generations 1992-1997 and 2004-2009 was a sufficient surrogate for presence during generation 1998-2003.

Area of Occupancy

Although potentially more useful, changes in the *AoO* are harder to quantify. By example and as a general rule, there is an increase in available records over the last two to three decades, thus there is also potential for an increase in the probability of a koala record being present in any given grid cell over that time period. The following procedures were applied in order to minimise the influence of chronological biases inherent in the data.

A 2.5km x 2.5km (625ha) grid overlay constrained by both the historical *EoO* and the TLGA boundary resulted in a series of hypothetical sampling cells. The 625ha grid cell size was considered the minimum necessary to accommodate spatial uncertainty in the data (use of different mapping datums, observer error etc), while the actual number of records themselves became academic; the primary scoring mechanism being whether a koala record was either present or absent. In order to deal with the disproportionately greater number of koala records in recent decades, each of the sampling iterations for this time period was based on a suite of randomly selected records, the number selected being equal to the total number of records for the preceding time period to which it was being compared. Fifty percent of the grid cells were then randomly selected in each of 10 iterations for each time period examined, with the number of cells within which koala records were present enumerated and converted to a proportion of the total area occupied. Differences between time periods were analysed using two-sample *t*-tests.

The issues of scale precluded a meaningful analysis of *AoO* within the TCSA.

Generational persistence

Derived from our earlier work in south-eastern Queensland and elsewhere in NSW (Phillips et al. 2007; Phillips and Hopkins 2010), we also employed the concept of "Generational Persistence Analysis" (GPA) to describe repeated records of koalas within a localised area over overlapping generational time spans and so identify the likely presence of resident and/or source populations. "Localised" was considered to include that area defined by the 2.5km grid cell around each koala record, with generational persistence inferred by overlapping records occurring over the course of three or more consecutive koala generations.

Such is the quantity of records in latter years, it was possible to undertake comparisons between two suites of three koala generations between 1980 and 2009

(Suite 1: 1980-1997; Suite 2: 1992-2009), thus potentially illustrating shifts in the extent and location of occupied areas otherwise masked in the preceding two analyses.

Results

Koala records

One thousand, six hundred and five (1,605) individual records were obtained for the TLGA, of which 1,218 had a date reliably attributed to them; hereafter we present results of analyses utilising only dated records. Once corrected for the presence of duplicate sightings, 1,119 records remained for analysis. The chronological distribution of koala records by koala generation is presented in Figure 2.1. The overall distribution of koala records for the TLGA is presented in Figure 2.2, the greater proportion of which (682) fell within the TCSA, while the number and source of records are presented in Table 2.1.

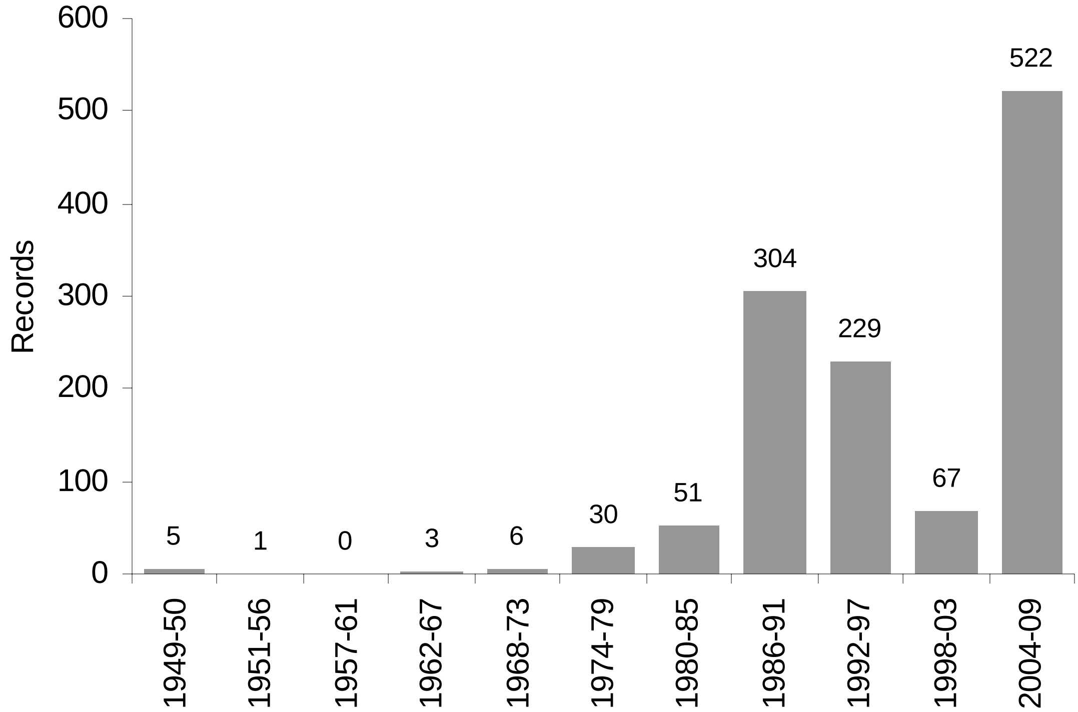


Figure 2.1. Chronological distribution of 1,218 koala records for the TLGA over the period 1949 - 2009.

Table 2.1. Source of koala records for the TLGA used in analysis of historical records. [1]Data supplied under license on 19th April 2010, records to April 2009; [2]records from May 1989 to

Dec 2009; [3]data supplied by Tweed Shire Council, reported in Kingston et al. (2004); [4]records from 1975 to 1993.

Source	Dated	Undated	Total
NPWS Wildlife Atlas[1]	696	-	696
Friends of the Koala Inc[2]	108	-	108
Tweed Community Survey[3]	-	269	269
Koala Rescue Unit[3,4]	414	118	532
Totals	1,218	387	1,605

Chronology of sightings

The earliest records of koalas in the TLGA occur in the Crystal Creek – Chillingham area, evidenced by two records from 1949, with only a further 13 added over the following 23 years. The contribution of records by the Koala Rescue Unit sees a significant increase in the number of records during the period 1975 to 1993. Koala records obtained during Dr. Dan Lunney's Community Wildlife Survey in 2006 along with records contributed by Friends of the Koala, record-keeping by local rescue and carer groups and local survey effort sees the largest numbers of records contributed during the last three to five years. The listing of the koala as a threatened species in NSW during the 1990s no doubt worked to elevate the species' profile and so increase the reporting rate throughout the TLGA.

The main clustering of records over time within the TCSA generally coincides with the location of larger remnants of forest vegetation and occur between Kingscliff and Cabarita and also between Clothiers Creek Road and (what is now) Koala Beach. Smaller clusters of records occur at Chinderah and in the Sleepy Hollow locality. North of the Tweed River, clusters of records occur on the eastern and western fringes of the Terranora Broadwater and south of the Cobaki Broadwater. A number of records are also present in the locality of the Fingal Golf Course at Tweed Heads South.

Over the last koala generation (2004-2009) there has been a notable decline in the reporting rate for the Tweed Heads area. For the years preceding 2004, numerous records exist from the areas of Tweed Heads South and Tweed Heads West, however relatively few records have been added in recent years. Those that are present are restricted to the northern and western periphery of the Terranora Broadwater. Of note also is the lack of records from the Wooyung area, with only a handful of scattered records present over the last two decades, although a koala population is known to have historically been present in the general area within the last three koala generations (S.Phillips unpub. data).

Extent of Occurrence

Available koala records for the TLGA reveal a historical *EoO* that approximates 130,240ha; this being the area captured by a MCP with vertices that intersect the outer-most koala records in the dataset. The *EoO* areas for the most recent three koala generations are variable, ranging from 58,092ha for the period 1998-2003 to 127,366ha over the period 2004-2009 (Figure 2.3). The overall trend in recent years (1992-2009) however is one of contraction; discounting the generation 1998-2003, a reduction in *EoO* area of approximately 18% is inferred. Locations which show a contraction in *EoO* over most recent generations are the far north-east and south-east of the study area.

The historical *EoO* for the TCSA approximates 29,600ha, which also evidences an average contraction of approximately 17% when changes in MCP size for each of the qualifying koala generations are averaged and then compared to that obtained using all available records (Table 2.2); range contractions are again most apparent in the far north, south and east of the study area (Figure 2.4).

Table 2.2. Percent changes in the *Extent of Occurrence* of koalas in the Tweed LGA and the study area.

	TLGA		TCSA	
Period	**EoO (ha)**	**% change**	**EoO (ha)**	**% change**
1949 - 2009	130,240	-	29,594	-
1992 - 1997	85,871	-34.1	21,575	-27.1
2004 - 2009	127,366	-2.2	27,320	-7.7
average change 1992 - 2009	106,618	-18.1	24,447	-17.4

Area of Occupancy

Comparison of AoO data for koalas in the TLGA between the periods 1949-1991 and 1992 onwards returned the following results:

1949 – 1991

Mean *AoO* estimated at 45.5 ± 2.8% (65,375 ± 4,000ha; 95% CI).

1992 – 2009

Mean *AoO* estimated at 44.3 ± 2.3% (63,625 ± 3,384ha; 95% CI).

Analysis of the data sets supporting these outcomes thus implies that while there appears to have been a slight decrease in the extent of the study area being occupied by koalas since 1992, the difference when compared to that of the previous 50 years is not statistically significant (t = 0.755, 18_{df}, $P > 0.05$).

Generational persistence

During the three koala generations from 1980 to 1997, available records for the TLGA indicate a number of areas of generational persistence, including localities in the north and southwest of Mount Warning – Wollumbin National Park. An area of approximately 1,875ha in the Burringbar – Mooball – Sleepy Hollow locality also indicates records persisting for these three generations. During this time period, koalas have been recorded from relatively large areas of the TCSA. An area of approximately 4,375ha reaching from Tweed Heads West through Banora Point, Chinderah, Cudgen and Kingscliff contains records from these years, as does a similar-sized area centred on the Duranbah, Bogangar and Round Mountain localities.

The subsequent three-generation subset (years 1992-2009) indicate an apparent increase in the area of generational persistence, with records from the aforementioned locations persisting through to 2009, along with an increase in repeated sightings over the three most recent generations throughout much of the Tweed Coast with the exception of Tweed Heads South, Tweed Heads West and the area between Mooball and Wooyung in the south (Figure 2.5).

Key Outcomes

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

- Reductions in the *Extent of Occurrence* of koalas within both the TLGA and the TCSA of at least 18% appear to have occurred over the last three koala generations. Range contraction is most apparent in the far northeastern and southeastern portions of the TCSA. Despite this trend however, analysis infers that there has not been any statistically significant change in the associated *Area of Occupancy* across the TLGA over the last three koala generations.

- Areas of generational persistence are scattered throughout the TLGA and are large and widespread throughout the TCSA.

- While able to illuminate general trends, results of analysis of the historical record must be treated with caution even when utilising relatively large data sets, due to inconsistency in reporting rates over time and the non-systematic nature of data collection.

Part 3

Field assessment

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 landscape-scale koala population conservation and management programs, it is equally, if not more important to determine the extent of current koala population distribution across the planning landscape. Hence the integration of historical record analysis with contemporary data on distribution ideally combines to identify key areas and thus form the basis for the focusing of management effort.

Standard approaches to addressing issues of koala distribution on a landscape scale variously rely on the extrapolation of localised survey data, broad-scale habitat modelling based on tree preference data, patch size and configuration, community reports and anthropogenic influence (eg. 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 identify areas of greatest importance to koala populations. Ideally, any approach to providing such information at both levels of investigation should be unbiased and systematic and thus scientifically defendable (MacKenzie 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, repeatedly demonstrating its ability to provide detailed information about koala population size, meta-population distribution and habitat use either at the macro-landscape scale or within localised areas (eg. Phillips et al. 2004; 2007; Phillips and Pereoglou 2005; Phillips and Hopkins 2010); it is this technique which formed the basis for field sampling throughout the TCSA.

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 obtain a field-based estimate of both the *EoO* and *AoO* within the TCSA;

(ii) to locate areas currently occupied by resident koala populations (*core koala habitat)*;

(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.

Methods

Site selection

Aerial photography flown in 2009 supplied by Tweed Shire Council coupled with vegetation mapping of Kingston et al. (2004), (updated to 2007 currency by BRS (2008)) were utilised for the purposes of selecting areas of vegetation to survey for koala activity. To ensure a uniform and unbiased distribution of survey effort across the TCSA we used a 1200m x 1200m point grid overlay, the resulting points then adopted as primary field sites where they intersected areas of remnant vegetation. Sites were excluded where any point fell within watercourses or cleared areas (not containing trees). Aerial photography for the immediate area surrounding each primary field site was inspected to determine the potential suitability of each for sampling by ensuring sufficient vegetation existed for the application of the sampling protocol. Universal Transverse Mercator (UTM) coordinates for the location of selected sites were uploaded into a Garmin GPS72 hand-held receiver navigating on the GDA datum. In the field, a level of flexibility was allowed in determining the exact position of the centre point of the site to enable the repositioning of a site into an area determined to be more suitable for sampling (from a koala habitat perspective) if this location was within 60m (5% of the sampling intensity) of the original site.

Supplementary field sites

Toward the latter part of the project we generated additional field sites to assist refinement of the metapopulation model (see below). Additional field sites were generated around those primary field sites that had returned a medium or high activity level and/or to refine metapopulation boundaries and were spaced at 600m intervals.

Assessment of habitat use

Once located in the field, each site was sampled using the Spot Assessment Technique (SAT) of Phillips and Callaghan (in press), 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. At each SAT site a 25m fixed radial search was also conducted for koalas, irrespective of the faecal pellet search result. If koala faecal pellets were recorded, an additional larger search area (approximating one hectare where practical) was surveyed for koalas. These searches involved three observers walking approximately 10m apart (depending upon visibility and terrain) and were conducted along transect-lines generally measuring 125m in two directions from the central point of the field site. The aim of both the radial search and transects were to enable area-based koala density estimates to be derived.

Metapopulation modelling

Koala 'activity' for each field site was determined by dividing the number of trees which scored positive for koala faecal pellets by the total number of trees searched in the site. Within the TCSA, we adopted the "*east coast med-high population density*" activity thresholds whereby an activity level of greater than or equal to 22.52% at a site indicated use by a *resident koala population* (Phillips and Callaghan in press). Koala activity levels for each site were then used to inform surface analyses using a combination of regularised splining and contouring to interpolate koala activity patterns. This process ultimately produces an activity contour map which – based on predetermined activity level thresholds – effectively delineates important "source" areas supporting resident koala populations. Based on previous studies (Phillips and Forsman 2005; Phillips and Pereoglou 2005; Phillips et al. 2007; Phillips et al. submitted), modelling invariably encapsulates areas occupied by approximately 85% of contemporary koala records and 100% of observed breeding females, the latter being one of the determinants of *core koala habitat* for the purposes of SEPP 44. It should be noted that boundaries modelled by the aforementioned process are indicative rather than definitive and potentially possess a generally outwardly radiating measure of uncertainty that is commensurate with sampling intensity.

Results

Habitat assessment

Sampling was undertaken between May and November 2010 during which time a total of 2,189 trees from 85 primary field sites were assessed. A number of planned sites were not sampled as a consequence of access difficulties (water) and/or refusal by some landholders to allow access onto their land.

Evidence of koala activity (i.e. faecal pellets recorded beneath at least one tree within the site) was recorded from sites across all land tenures. Koala activity was spatially auto-correlated (clustered) and recorded most commonly from sites in the central portion of the study area (Figure 3.1), with a small number of outliers (n=6) in the northern and western portions of the study area. Koala activity was recorded at 17 of the 85 primary sites within which koala activity levels ranged from 3.57% - 86.67% [mean activity level (active sites only): 26.11 ± 25.33% (SD)]. This result also translates to an *EoO* approximating 12,631ha when sites returning koala activity are enclosed in a MCP (incorporating a buffer of 600m to account for sampling intensity), and an associated *AoO* of 20.00 ± 8.50% (95%CI). Eight of the 17 sites returned activity levels at or above the 22.52% activity threshold known to indicate use by a resident koala population, thus allowing us to also derive an estimated *Area of Residency* of 13.79 ± 8.93% (95%CI).

Supplementary field sites

A further 49 supplementary field sites were sampled, 38 of which returned evidence of koala activity ranging from 3.85% - 100%. Table 3.1 provides a summary of total survey effort accumulated during field sampling. Locations of field sites and associated activity levels are provided in Appendix I.

Table 3.1. Summary of effort undertaken during field sampling within the Tweed Coast study area.

	Primary sites	Supplementary sites	Totals
Field sites	85	49	134
Active sites	17	38	55
Sites with significant activity	8	23	31
Trees sampled	2,189	1,235	3,969
Area searched for koalas (ha)	28.64	39.06	67.70

Metapopulation modelling

The spatial auto-correlation in the distribution of active sites provides confidence in terms of modelling the associated activity data such that indicative boundaries indicating occupancy by resident koala populations within the TCSA can be determined. The resulting model (Figure 3.2) identifies three small population cells within the TCSA described as follows:

1. Bogangar – Kings Forest – Forest Hill

Located north of Cudgen Lake in the central portion of the TCSA, this metapopulation cell extends from the Depot Rd area of Kings Forest to Forest Hill in the south, encompassing lands adjacent to Tweed Coast Road and covering a portion of Cudgen NR as well as the southern portion of Kings Forest. This cell is approximately 360ha in size, approximately 70% of which is vegetated lands.

2. Tanglewood – Round Mountain – Koala Beach

Located to the west of Cabarita and generally bordered in the north by Clothiers Creek Road and extending south to Koala Beach, this metapopulation occupies a large proportion of Cudgen NR, extending into the outskirts of Cabarita, crossing Clothiers Creek Rd in the north and extending into fragmented vegetation to the south of Tanglewood Village. An area of approximately 580ha is recognised as supporting resident koala populations at this time, however the contorted nature of this metapopulation boundary suggests previous disturbance in the Tanglewood area as evidenced by concave areas in the modelled boundary. This cell potentially has connectivity with the Bogangar – Kings Forest – Forest Hill cell to the north, and to the south across Round Mountain Rd where significant activity extends into the north of forested lands surrounding the Koala Beach estate, concordant with data collected independently in 2010 by John Callaghan (T. Fountain pers. comm). Significant activity was also recorded within a localised area in the south of Koala Beach. Collectively, approximately 80% of the above lands are theoretically capable of supporting koala populations.

3. Pottsville Wetlands – Black Rocks

Located to the south of the preceding cell but separated from it by a distance of approximately 3km this cell is almost entirely contained within the Pottsville Wetlands reserve, but is otherwise bordered in the north by Pottsville Road and to the east by the Black Rocks residential estate. It is known that this metapopulation extends to the south to occupy some vegetated areas of the Dunloe Park area, (based upon data collected during the course of the World Rally Championship event (Phillips and Hopkins 2009)). Due to the reluctance of landholders to allow sampling in this area however, the southern boundaries of this cell remain undefined. Habitat quality and connectivity suggest a high carrying capacity in this cell, which otherwise occupies approximately 320ha.

The presence of significant activity in the Duranbah – Eviron Road locality suggests the existence of a further resident population in the area, potentially extending to the western side of the Pacific Highway. Metapopulation boundaries are difficult to define in these areas due to the fragmentation of vegetation and sampling scale, suffice to say that carrying capacity east of the Highway in this particular area is low.

Population estimate

During sampling of primary field sites, approximately 28.64 hectares were surveyed for koalas (13.61ha during radial searches at primary field sites and 15.03ha associated with transect searches). No koalas were observed during these searches. A further 39.06ha of survey effort was accumulated during sampling of supplementary field sites, within which four koalas were recorded. Using the 31 field sites that returned significant koala activity levels, this outcome allows a density estimate of 0.14 ± 0.12 (95% Confidence Interval (CI)) koalas ha^{-1} to be determined. Population estimates, adjusted to account for the available habitat in each cell, infer a total population size of between 25 and 267 koalas with an estimate of approximately 144 koalas for currently occupied areas of the TCSA (Table 3.2).

Table 3.2. Koala population estimates (N) for currently occupied areas of the TCSA based on the density estimate determined by field survey.

Locality	Cell size (ha)	Available habitat	Population estimate		
			Lower 95% CI	N	Upper 95% CI
Bogangar – Kings Forest – Forest Hill	358	71%	5	36	66
Tanglewood – Round Mountain – Koala Beach	578	80%	9	64	120
Pottsville Wetlands – Black Rocks	316	79%	10	35	65
Duranbah – Eviron	625	10%	1	9	16
Total			**25**	**144**	**267**

An additional three koalas were observed opportunistically during field sampling; the locations of koala sightings are indicated on Figure 3.2.

Key outcomes

- Distribution of koala activity is widespread throughout the TCSA but field data points to a significantly smaller *EoO* than that alluded to by analysis of historical records, while the associated *AoO* also appears to have more than halved when compared to that indicated by analysis of the historical record. The proportion of habitat occupied by source populations within the TCSA has been estimated at less than 14% of the total area of eucalypt forest potentially available to the species.

- Metapopulation modelling based on koala activity data has resulted in identification of three disjunct areas containing resident koala populations, collectively comprising approximately 1,030ha of habitat in the central portion of the TCSA in the general localities of Kings Forest, Round Mountain and Pottsville Wetlands.

- While koala activity was detected to the north and west outside of the abovementioned localities, the long-term prognosis for these outliers is poor in the absence of recruitment from other source populations.

- A density estimate of approximately 0.14 koalas per hectare has been derived for areas currently supporting resident koala populations, resulting in a population estimate of approximately 144 koalas inhabiting such areas in the TCSA.

Part 4

Food tree preferences & habitat mapping

Introduction

Koala habitat mapping provides an essential basis for (i) understanding the distribution and abundance of koala habitat, (ii) for effective conservation planning, and (iii) 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 use by koalas and invariably these are the species' preferred food trees. It is widely recognised that koalas prefer a relatively small number of the *Eucalyptus* species in any given area (e.g. Hindell and Lee 1987; Ellis et al. 1999, 2002; Lunney et al. 1998, 2000; Martin and Handasyde 1999; Phillips et al. 2000; Phillips and Callaghan 2000; Smith 2004; Moore et al. 2004). The identification of preferred tree species across large and heterogenous landscapes can be a complex process, as it is recognised that a number of factors influence the way koalas utilise their preferred suite of eucalypts, including the extent of habitat fragmentation, historical disturbance, stochastic events such as fire, and the nutrient status of the soil (Moore and Foley 2000; Phillips and Callaghan 2000; McAlpine et al. 2006). This variability is also recognised in the Approved Recovery Plan for Koalas in NSW (DECCW 2008) 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 meaningful map of potential koala habitat is not only contingent upon 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 and soil mapping layers. Subject to such qualifications, the analyses described in this section provides the basis for understanding the utilisation of eucalypts by koalas throughout the TCSA, our objectives for this component of the study being to:

(i) identify preferred koala food trees for the TCSA, and

(ii) produce a map of *potential koala habitat*.

Methods

The data set for this component of the study comprised tree use data from 35 primary and supplementary field sites described in the previous section wherein koala activity (i.e. the presence of koala faecal pellets) was recorded. Additional data from the Tweed Coast Koala Habitat Atlas (Phillips and Callaghan 1996) and the Draft Kings Forest KPoM (Phillips and Pereoglou 2004) was also combined with our data set in order to provide a larger data set for analysis. The combination of data was made possible because sampling methodology of these earlier studies was consistent with that adopted for the purposes of this study.

Taxonomic uncertainty

To further assist analyses, tree species identified as the ironbark *Eucalyptus crebra* by Phillips and Callaghan (1996) were redefined as *E. siderophloia*, while *E. acmeniodes* and *E. carnea* in the coastal lowlands were pooled. The naturally occurring *E. robusta* x *E. tereticornis* hybrid – referred to as *E. 'patentinervis'* by Bale (1996) was referred to *E. tereticornis* for the purposes of this study. Any individual *Eucalyptus* tree species for which there was taxonomic uncertainty was excluded from the data set as were all non-eucalypt tree species identified only to genus level.

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 utilisation "*P*" – hereafter referred to as the 'strike-rate'. Strike-rates were calculated by dividing the number of trees which had one or more koala scats at their base, by the total number of sampled trees. Strike-rate data was subsequently divided into primary and secondary data sets, the primary data set consisting of tree species for which the number of sites from which it was sampled was greater than five, and n_iP_i and $n_i(1\text{-}P_i)$ was greater than or equal to 30. Thus, the primary data set contained the most commonly sampled tree species as well as those being most frequently utilised by koalas and thus most likely to be of some importance in sustaining the population.

The extent of variation amongst strike rates within resulting data sets was examined using log-likelihood ratios, significant heterogeneity 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.

Logistic regression was used to examine any perceived trends in differential size-class-based utilisation of tree species by koalas.

Influence of soil landscape on use of PKFTs

Because the use of certain tree species by koalas varies with soil type (Phillips 2000b, Phillips and Callaghan 2000, Moore and Foley 2005) it cannot be assumed that tree preferences will remain 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:

(i) sites on all erosional/residual landscapes (Nerang-Fernleigh Metamorphics (NFM)) and

(ii) those of transferral, alluvial, estuarine, beach, aeolian and swamp (TAEBAS) landscapes respectively.

Stratification of sites by soil type was based on the mapping of Morand (1996). For the purpose of analysis, data for each species were firstly aggregated by soil landscape and allocated to data sets on the basis of statistical criteria outlined above.

Habitat categorisations

The vegetation mapping work of Kingston et al. (2004) provided the basis for koala habitat classifications. Vegetation communities were categorised in accord with the definitions detailed below; such ecologically-based determinations considered to better reflect the extent of *potential koala habitat* for the purposes of SEPP 44 than that otherwise obtained using the 15% rule (see SEPP 44, Part 1, 4 Definitions). The terms “Primary”, “Secondary” and “Supplementary” food tree species are based on the mathematical models and associated definitions of Phillips (2000b) and are consistent with terminology used in the Recovery Plan for the Koala (DECC 2008) and outlined below.

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.

Secondary (Class A) Habitat – areas of forest and/or woodland wherein primary food tree species are present but not dominant or co-dominant and usually (but not always) growing in association with one or more secondary food tree species.

Secondary (Class B) Habitat – areas of forest and/or woodland wherein primary food tree species are absent, habitat containing secondary and/or supplementary food tree species only.

A habitat code of "**Other**" was applied to those communities within which koala food trees were absent. Areas for which insufficient information regarding community composition was available were typed as "**Unknown**".

Results

Preferred koala food trees (PKFTs)

From a total dataset (all sites) of 8,413 trees, a sub-set of 4,771 trees from 139 active sites was potentially available for analyses (Table 4.1). After pooling of taxonomic equivalents, a data set of 4,313 trees comprising nine species of *Eucalyptus* and 10 non-eucalypt species was available for more detailed examination.

Table 4.1. Breakdown of the tree-use data set used for determination of preferred koala food tree species in the TCSA. [1]Phillips and Callaghan (1996); [2]Phillips and Pereoglou (2004).

	Habitat Atlas[1]	Kings Forest[2]	This study	Total
Active sites	52	53	35	140
Trees in actives sites	2517	1575	911	5003
Inactive sites	18	34	71	123
Trees in inactive sites	771	816	1823	3410
Total number of sites	70	87	106	263
Total number of trees	3288	2391	2734	8413

For those species meeting criteria for statistical analysis, Figure 4.1 illustrates the overall result arranged in terms of decreasing strike-rates for eucalypt and non-eucalypt data sets respectively across all soil landscapes. Swamp Mahogany *Eucalyptus robusta* and Forest Red Gum *E. tereticornis* are clearly the most preferred tree species, their strike-rates of approximately 50% confirming their role as primary koala food trees. Tallowwood *E. microcorys* and Grey Gum *E. propinqua* are the next most preferred, the strike-rate of *E. microcorys* however being lower than otherwise expected. In general terms strike-rates for the remaining eucalypts and non-eucalypts indicate levels of non-preferential and/or opportunistic browsing, the higher level of the non-eucalypts *Callitris columellaris* and *Melaleuca quinquenervia* associated with proximity to the more preferred species such as Swamp Mahogany and Forest Red Gum.

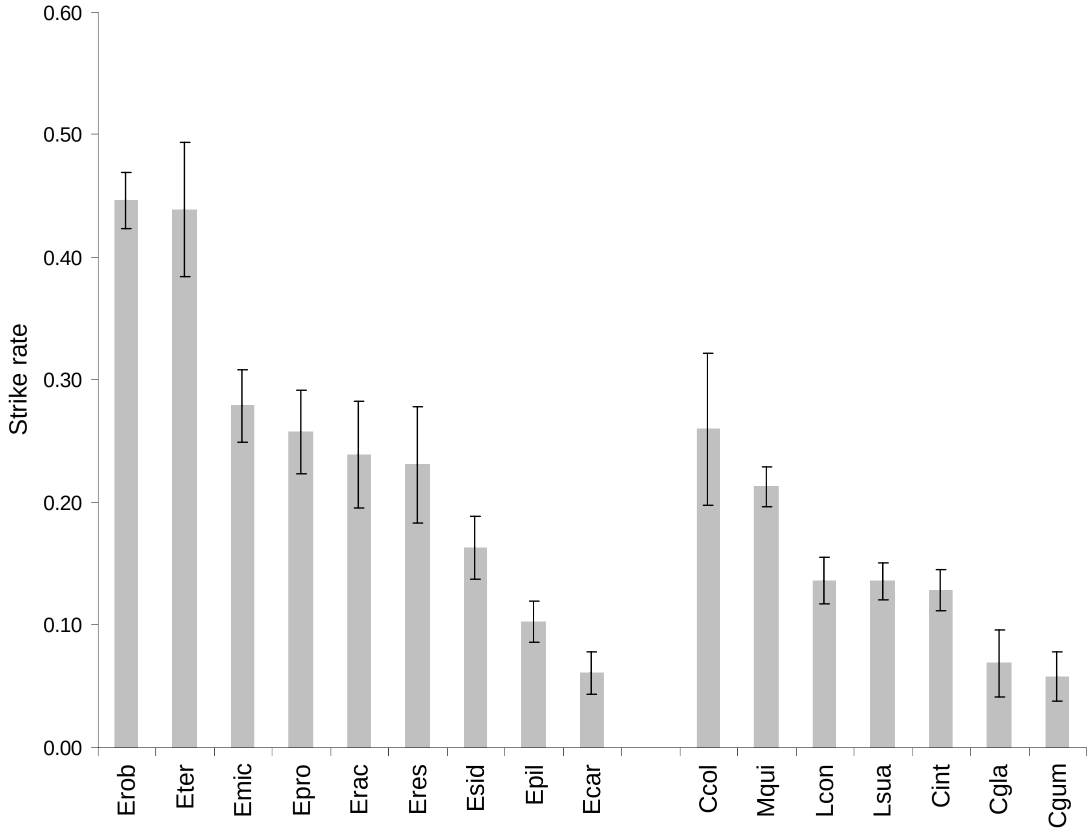


Figure 4.1. Summary of strike-rate data from active SAT sites within the TCSA. Strike rates are presented as the pooled proportion of each species sampled that were recorded with faecal pellets, vertical bars represent ± standard error for species constituting parametric and non-parametric data sets only. *Erob=Eucalyptus robusta, Eter=E. tereticornis, Emic=E. microcorys, Epro=E. propinqua, Erac=E. racemosa, Eres=E. resinifera, Esid=E. siderophloia, Epil=E. pilularis, Ecar=E. carnea/acmeniodes, Ccol=Callitris columellaris, Mqui=Melaleuca quinquenervia, Lcon=Lophostemon confertus, Lsua=L. suaveolens, Cint=Corymbia intermedia, Cgla=Casuarina glauca, Cgum=Corymbia gummifera*

Table 4.2 provides a breakdown of tree species contributing to the preceding figure in terms of their occurrence on the two aggregated soil landscape categories recognised for the purposes of this study, while Table 4.3 provides a corresponding summary of those tree species associated with non-active sites.

Table 4.2. Breakdown of tree species recorded in active SAT sites in terms of the two generic soil landscape categories recognised for purposes of this study. Tree species are arranged in alphabetical order. P=strike rate, n=number of trees, SE=standard error, * indicates inclusion in primary data sets.

	Soil landscape category					
	NFM			TAEBAS		
	Sites	*n*	*P* ± SE	Sites	*n*	*P* ± SE
Eucalypts						
E. carnea/E. acmenoides	16	193*	0.06 ± 0.02	1	2	0.00
E. microcorys	41	219*	0.26 ± 0.03	3	7	0.50 ± 0.13
E. pilularis	39	333*	0.10 ± 0.02	4	8	0.13 ± 0.12
E. propinqua	27	161*	0.26 ± 0.03	1	2	0.00
E. racemosa	-	-	-	13	96*	0.24 ± 0.04
E. resinifera	14	73*	0.21 ± 0.05	2	5	0.60 ± 0.22
E. robusta	2	3	0.67 ± 0.27	52	474*	0.45 ± 0.02
E. siderophloia	32	200*	0.16 ± 0.03	1	8	0.38 ± 0.17
E. tereticornis	4	10	0.30 ± 0.14	13	72*	0.46 ± 0.06
Non-eucalypts						
Callistemon salignus	4	12	0.17 ± 0.11	8	15	0.13 ± 0.09
Callitris columellaris	-	-	-	6	50*	0.26 ± 0.06
Casuarina glauca	5	25	0.04 ± 0.04	6	62*	0.08 ± 0.03
Cinnamomum camphora	4	18	0.11 ± 0.07	3	9	0.44 ± 0.17
Corymbia gummifera	10	71*	0.10 ± 0.04	12	67	0.01 ± 0.01
C. intermedia	41	277*	0.13 ± 0.02	17	104*	0.13 ± 0.03
Lophostemon confertus	32	197*	0.13 ± 0.02	18	134*	0.14 ± 0.03
L. suaveolens	4	13	0.23 ± 0.12	29	502*	0.13 ± 0.02
Melaleuca quinquenervia	6	53	0.34 ± 0.07	56	553*	0.20 ± 0.02
Pinus elliottii	-	-	-	19	246	0.11 ± 0.02
Total trees		**1897**			**2416**	

Table 4.3. 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 soil landscape categories. "Other spp" category includes species from the Genera *Acacia, Allocasuarina, Banksia, Callistemon, Melaleuca, Leptospermum* and various rainforest species. Tree species are arranged in alphabetical order.

	Soil landscape category			
	NFM		TAEBAS	
	Sites	*N*	Sites	*n*
Eucalypts				
E. carnea/E. acmenoides	10	36	-	-
E. grandis	2	2	2	17
E. microcorys	15	58	-	-
E. pilularis	21	146	2	6
E. propinqua	12	75	2	6
E. racemosa	-	-	5	13
E. resinifera	1	3	2	5
E. robusta	2	4	15	234
E. saligna	1	2	-	-
E. siderophloia	16	96	2	13
E. tereticornis	8	51	12	92
Other *Eucalyptus* spp.	5	9	4	4
Non-eucalypts				
Callistemon salignus	3	8	-	-
Callitris columellaris	-	-	2	31
Casuarina glauca	1	1	7	34
Cinnamomum camphora	9	53	8	28
Corymbia gummifera	3	9	7	16
C. intermedia	26	98	9	94
Lophostemon confertus	22	175	8	35
L. suaveolens	7	40	14	101
Melaleuca quinquenervia	4	49	47	614
Pinus elliottii	4	26	21	267
Other spp.	32	352	48	507
Total trees		**1293**		**2117**

a) NFM soil landscape category

Data from six species of eucalypt and three species of non-eucalypt formed the primary data set for analysis purposes within which strike-rates ranged from 26.5% for Tallowwood *E. microcorys* to 6% for White Mahogany *E. carnea/E. acmenoides.* There was significant heterogeneity amongst the strike-rates (G = 58.2032, 8_{df}, $P < 0.001$), with an unplanned test for homogeneity using simultaneous test procedures clearly isolating Tallowwood *E. microcorys* and Grey Gum *E. propinqua* as the most preferred tree species being utilised by koalas. Figure 4.2 illustrates the distribution of strike-rates for the nine species analysed, along with constituent homogenous sub-sets.

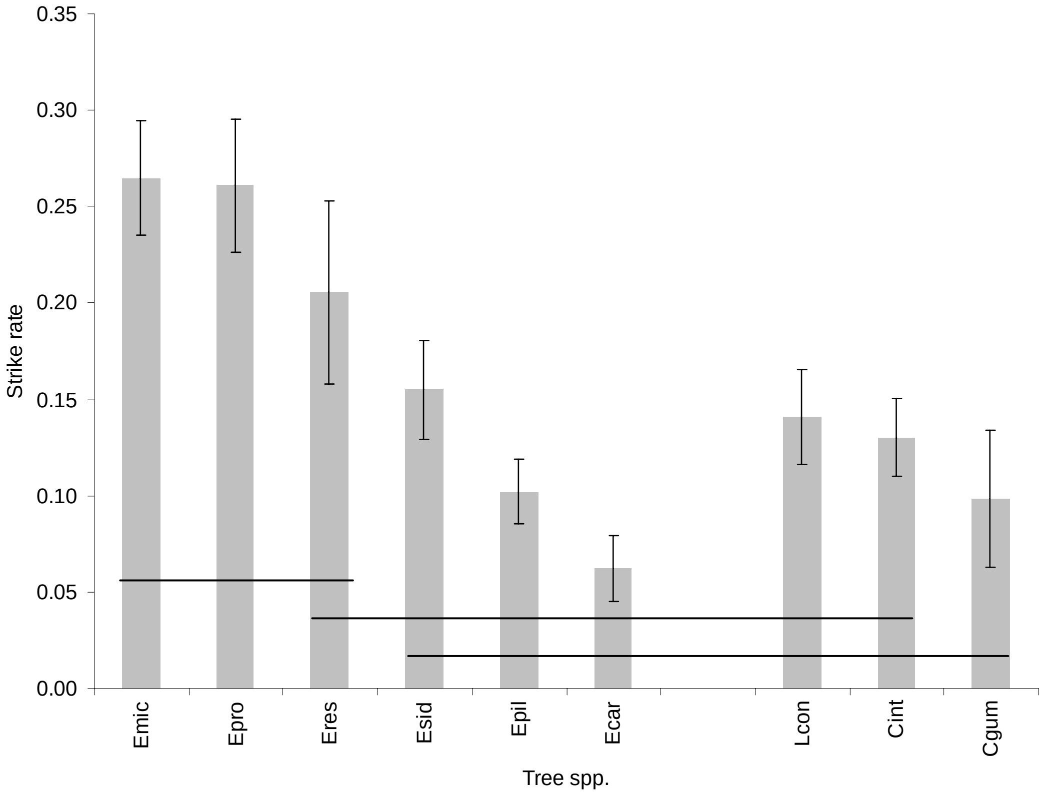
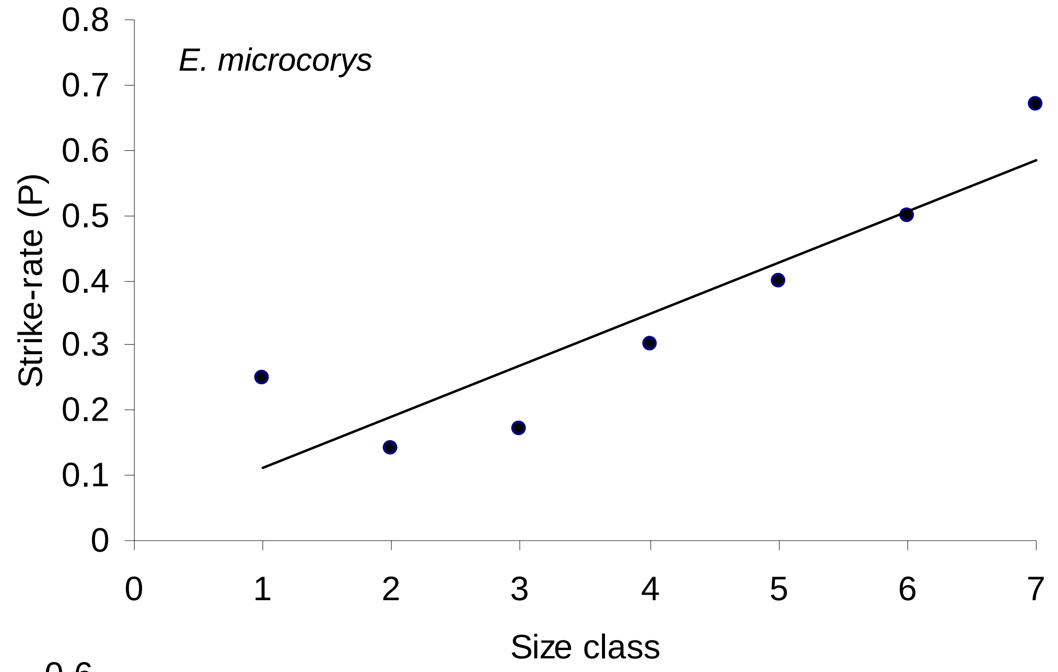


Figure 4.2. Summary of tree species utilisation at active SAT sites on the NFM generic soil landscape category. Strike rates are presented as the pooled proportion of each species recorded with faecal pellets, vertical bars represent ± standard error. Horizontal lines indicate non-significant subsets resulting from the unplanned test for homogeneity. *Emic = Eucalyptus microcorys, Epro = E.propinqua, Eres = E.resinifera; Esid = E. siderophloia, Epil = E. pilularis, Ecar = E. carnea/acmeniodes, Lcon = Lophostemon confertus, Cint = Corymbia intermedia Cgum = C. gummifera*.

Preferential utilisation of both *E. microcorys* and *E. propinqua* was also positively associated with trees in the larger size classes. Figure 4.3 illustrates the scatterplots and associated trendlines using a complex maximum likelihood model based on logistic regression.



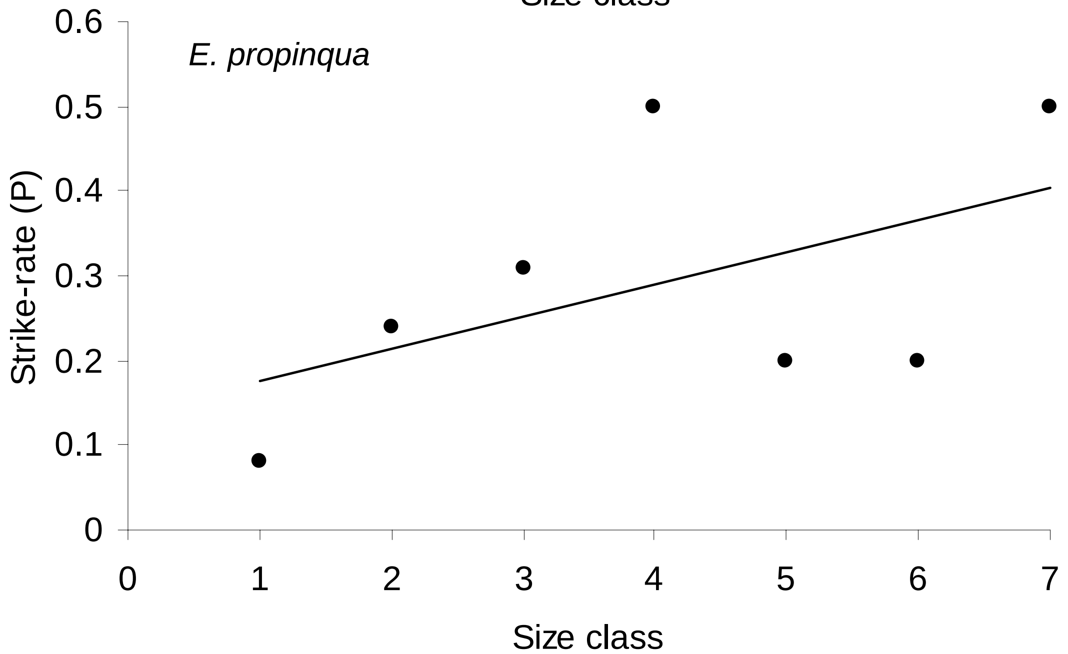


Figure 4.3. Size-class based levels of utilisation for secondary food tree species *E. microcorys* (top) and *E. propinqua* (bottom) on the aggregated soil landscape category "NFM" in the TCSA (Maximum likelihood test for overall lack of fit (pooled data set): $G = 9.026$, 1_{df}, $P < 0.01$). X-axis figures 1 - 6 indicate 100mm size class increments (starting at 1 = 100-199mm dbhob), 7 = all size-classes > 700mm)

With the possible exception of *E. tereticornis*, data sets for tree species excluded from the primary data set were generally considered of little utility and no further analyses were undertaken.

b) TAEBAS soil landscape category

Data from three species of eucalypt and six species of non-eucalypt formed the primary data set for analysis purposes within which strike-rates ranged from 46% for Forest Red Gum *E. tereticornis* to 8% for Swamp Oak *C. glauca*. There was significant heterogeneity amongst the strike-rates (G = 179.364, 8_{df}, P < 0.001), with an unplanned test for homogeneity using simultaneous test procedures isolating *E. tereticornis* and *E. robusta* as the most preferred tree species. Figure 4.4 illustrates the distribution of strike-rates for the nine species analysed, along with indications of constituent sub-set homogeneity.

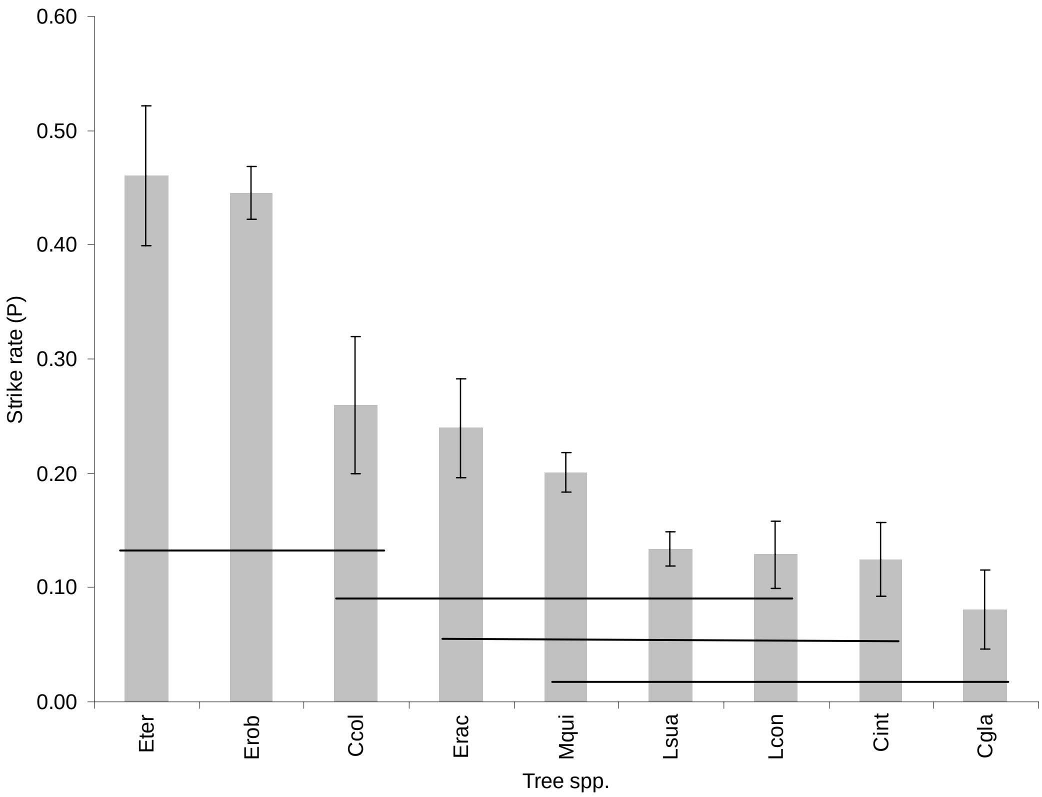


Figure 4.4. Summary of tree species utilisation at active SAT sites on the TAEBAS generic soil landscape category. Strike rates are presented as the pooled proportion of each species recorded with faecal pellets, vertical bars represent ± standard error. Horizontal lines indicate non-significant subsets resulting from the unplanned test for homogeneity. *Eter = Eucalyptus tereticornis, Erob = E.robusta, Ccol = Callitris columellaris; Erac = E. racemosa, Mqui = Melaleuca quinquenervia, Lsua = Lophostemon suaveolens, Lcon = L. confertus, Cint = Corymbia intermedia, Cgla = Casuarina glauca.*

With the possible exception of *E. microcorys,* data sets for tree species excluded from the primary data set were generally considered of little utility and no further analyses were undertaken.

c) Differences between generic soil landscapes

Of the tree species identified as most preferred by koalas, only *E. microcorys* and *E. tereticornis* indicated trends that inferred a possible change in food tree status, the strike rate of *E. microcorys* on TAEBAS being higher than otherwise expected (50% on TAEBAS *vs* 26% on NFM), while that of *E. tereticornis* on NFM lower than expected (30% on NFM *vs* 46% on TAEBAS).

Habitat categorisations

Tweed Shire vegetation mapping (Kingston et al. 2004) describes 46 vegetation communities for consideration as koala habitat within the TCSA, collectively capturing approximately 19,154ha (98%) of the TCSA within 2,808 individual polygons varying in size from less than 0.01ha to 12,136ha (mean polygon size 7.42ha ± 230.28ha(SD)). Based on the tree use data set and associated analyses, the following decision path formed the basis for habitat classification:

1. Eucalyptus tereticornis *and* E. robusta *function as <u>primary</u> food tree species in vegetation communities growing on TAEBAS soil landscapes within the study area.*
2. Eucalyptus microcorys *and* E. propinqua *function as <u>secondary</u> food tree species in vegetation communities growing on NFM soil landscapes within the study area.*
3. *The higher strike-rate of* E. microcorys *infers <u>primary</u> food tree status when growing on TAEBAS soil landscapes.*[1]
4. *The lower strike-rate of* E. tereticornis *infers <u>secondary</u> (or lower) food tree status when growing on NFM soil landscapes.* [1]

Application of the preceding decision path to those communities comprising the vegetation mapping data layer in accord with the definitions adopted by this study resulted in approximately 3,815ha of *potential koala habitat* being identified within the study area (Figure 4.5, Table 4.4).

[1] Supported by results of other studies (Phillips and Hopkins 2009)

Table 4.4. Mapped area in hectares for each category of koala habitat identified within the TCSA.

	Habitat Quality	Area (ha)	% of total
Potential koala habitat	Primary	200	1.04
	Secondary A	2,300	12.01
	Secondary B	1,315	6.87
Other habitat	Other	2,361	12.33
	Unknown	12,978	67.75
	Totals	**19,154**	**100.00**

Primary Koala Habitat

Primary Koala Habitat is limited to 200ha (1.04%) of mapped vegetation and consist of communities that are dominated by *E. robusta* and/or *E. tereticornis* ± *E. microcorys* growing on TAEBAS soil landscapes.

Secondary (Class A) Habitat

Secondary (Class A) Habitat comprises the bulk of *potential koala habitat*, encompassing 2,300ha (12%) of mapped vegetation communities growing on TAEBAS soil landscapes wherein on average *E. robusta* and/or *E. tereticornis* ± *E. microcorys* are sub-dominant elements.

Secondary (Class B) Habitat

Secondary (Class B) Habitat comprises 1,315ha (6.8%) of mapped vegetation communities containing *E. microcorys* and/or *E. propinqua*, growing on NFM soil landscapes.

Other Habitat

Approximately 2,361ha of mapped vegetation does not support PKFTs, comprising 12.33% of the vegetation mapped within the study area. This habitat category is comprised of vegetation communities such as exotic plantation, mangroves and rainforest.

Unknown Habitat

A total of 12,978ha (67.75%) of possible habitat was unable to be classified due to a lack of information regarding floristic composition. The greater proportion of this category (95.8% or 12,436ha) comprises areas classified as "Substantially Cleared of Native Vegetation". While this mapping category includes urban areas, roads and beach sand, it also encompasses lands with scattered vegetation which in some areas would qualify as *potential koala habitat*.

A detailed breakdown of each of the mapped vegetation communities within the study area and their associated koala habitat categorisations is provided in Appendix II.

Key outcomes

- Trends in the tree use data set demonstrate a suite of eucalypt species comprising Swamp Mahogany *E. robusta,* Forest Red Gum *E. tereticornis,* Tallowwood *E. microcorys and* Grey Gum *E. propinqua* that are the most preferred tree species for koalas in the study area.

- Statistical analysis isolates Forest Red Gum *E. tereticornis* and Swamp Mahogany *E. robusta* as the most preferred tree species across transferral, alluvial, estuarine, beach, aeolian and swamp landscapes in the study area. Tallowwood *E. microcorys* and Grey Gum *E. propinqua* by koalas were isolated as the most preferred tree species across erosional and residual soil landscapes.

- Tallowwood *E. microcorys* and Grey Gum *E. propinqua* exhibit differential selection by koalas whereby trees of larger size-class are preferred over smaller individuals of the same species.

- A total of 3,815ha of *potential koala habitat* is identified based on available vegetation mapping. All three habitat categories recognised by the Recovery Plan are represented. Primary Koala Habitat is the least well represented and comprises approximately 1% of the total area of mapped vegetation.

- A proportion of lands classified as "Unknown" for the purposes of this report comprise polygons classified as "Substantially Cleared of Native Vegetation" with scattered vegetation, which in some areas would constitute potential koala habitat due to the presence of preferred koala food trees.

Part 5

Threatening processes

1. Habitat loss & linkages

Loss of potential koala habitat continues to contribute to population decline across the koala's range. Across the TLGA, approximately 965ha of bushland vegetation was removed between 2000/2001 and 2007 (BRS 2008). A disproportionate amount of this loss has occurred within the TCSA wherein approximately 100ha of potential koala habitat has been lost during this same period. This is a significant loss in an area where habitat is continually under pressure from inappropriate land clearing and is becoming increasingly fragmented.

The influence of patch size, patch shape and level of connectivity are key factors determining the ability of a landscape to support viable koala populations. McAlpine et al*.* (2007) suggest that the probability of koalas being present falls as the percentage of the landscape containing forest communities decreases, while it has also been suggested that the chance of koalas being present starts to decline once patches become smaller than ~150ha. Isolation of patches may also be an important predictor of koala occurrence with koalas more likely to occur in patches close to (within ~100m) other patches than in isolated patches. Small populations that are highly isolated tend to suffer higher extinction risks than populations that are connected to each other via animal movement. Immigration or recruitment into a population can provide a 'rescue' effect and can help maintain genetic diversity. The survival of meta-populations (a group of sub-populations connected by dispersal) relies on the ability of animals to recolonise habitat patches where a sub-population has become locally extinct. Whilst habitat patches that are further apart are often considered less connected than patches close together, connectivity also depends upon the nature of the matrix and the existence of barriers to movement.

The maintenance of habitat patches of sufficient size to support existing populations and provide for future population expansion is fundamental to koala population and habitat management within the TCSA. To this end a three-faceted approach will be required, consisting of the following foci.

1. Retention of potential koala habitat *in-situ* in the first instance, with a focus on occupied habitat, and adjoining areas of potential koala habitat. Protection of bushland containing large size-class Tallowwood and Grey Gum is also necessary to preserve the habitat resource on NFM soil landscapes.
2. Maintenance and creation of vegetated linkages between habitat patches and source populations.

3. Strategic revegetation work with the aim of consolidation of existing habitat patches and habitat creation. Revegetation work should focus primarily on "gap-filling" in large habitat blocks within and adjacent to mapped source populations, edges of habitat blocks and within linkage areas.

Indicative linkage areas for the focusing of habitat retention and creation are provided in Figure 5.1.

2. Fire

Stochastic and poorly-planned fire events continue to threaten koala populations throughout the east coast, and are increasingly being recognised as a key factor influencing long-term viability (Phillips and Pereoglou 2005, Phillips and Hopkins 2010). Wildfire has the potential to exacerbate koala population decline (Starr 1990; Melzer et al. 2000) as each high-intensity or high-frequency fire within areas occupied by resident populations removes a proportion of the breeding population at a rate faster than the time required for the loss to be replaced by successive koala generations. Fire removes the food resource from remaining koalas not killed by fire and widespread canopy scorch presumably results in starvation for the remaining animals (Melzer *et al*. 2000).

Wildfire has the potential to impede recovery, particularly when population size and occupancy is already low. Where the bulk of the population is contained in small isolated areas, as is now the case in the TCSA, it is highly vulnerable to impacts arising from a single major wildfire. Indeed in a number of areas sampled for koala activity during these assessments, koala activity was dated pre-fire, with no evidence of continued occupation post-fire (evidenced by old, scorched pellets and the absence of new, fresh pellet deposition). Observations made during the course of the field assessment infer an unacceptable number of both high intensity and high frequency fire events over recent years in key habitat areas.

The majority of the bushland area surrounding Cudgen Lake in the centre of the TCSA has been subject to wildfire at some stage in the 15 year history of fire reporting available to this study (DECCW records). Additionally, a large proportion of this area, particularly to the north and west has been burnt on more than one occasion, with intervening intervals of as short as three years. Fifteen occurrences of wildfire have been recorded and mapped in the area since 1982. The two most recent fires, in 2009 and 2004 (Figure 5.2) extended over much of the forested area to the north, west and south of Cudgen Lake, and have been high-intensity burns. The influence of the most recent fires on distribution of significant koala activity is also visible in Figure 5.2, with the majority of the area affected by the 2009 wildfire as well as a large proportion of the 2004 wildfire area currently unoccupied, despite the presence of high quality habitat. It is these latter two events that we see as primarily responsible for the population attrition documented by the field survey component of our study.

3. Road mortalities / koala blackspots

A common phenomenon arising from investigation of koala sightings is the longitudinal arrangement of clusters of koala records, which effectively delineate major roads. This is true for parts of the Tweed Coast Road, Clothiers Creek Road, Round Mountain Road, Pottsville Road and parts of the Pacific Highway. Within the TCSA by example, 22.1% of available records occur within 100m of the above roads (Figures 5.3a and 5.3b). Phillips (2002) reported vehicle-strike as responsible for 34% of koala mortality on the Tweed Coast. While this statistic has decreased to 19% in the intervening decade, this result is more likely to be attributable to overall population decline than an increase in care and vigilance of drivers. Although the total number of records attributable to road-strike is certainly greater, known records of koalas hit by cars (due to the detail supplied in records from FoK) occur on the Pacific Highway from Sextons Hill through to Crabbes Creek (n=7), Clothiers Creek Road (n=1) and Round Mountain/Kanes Road (n=1). The majority of these roads are known koala road mortality hotspots in the area, however few are identified with signage, and where signage exists, it appears to do little to reduce vehicle speeds. A brief examination of each koala blackspot is provided below.

Clothiers Creek Road

Clothiers Creek Road runs east-west for approximately 4.6km between the Pacific Highway and the coastal village of Cabarita. Approximately 2.7km of the eastern section of the road passes through Cudgen Nature Reserve, with the entire length of this section bounded on at least one side by vegetation communities mapped as Primary, Secondary A and Secondary B koala habitat. Twenty-eight records of koala sightings are present for the vicinity of the road, of which 18 are located in the eastern section. Clothiers Creek Rd is a known vehicle strike hotspot for the Tweed

Coast, with Phillips (2002) reporting that it accounted for 47% of known roadkills between 1991 and 2000. The eastern section of the road passes through portions of mapped source populations and a major vegetated link (Figure 5.1), thus it is this portion of road that poses greatest threat to individual koalas occupying or moving through habitat adjacent to the road.

The statutory speed limit for Clothiers Creek Road between Tanglewood and Bogangar is 70km/h, reduced to 60km/h on the approach to Bogangar in the east. Traffic data from between 2002 and 2009 however indicate that actual average traffic speeds range from 65km/h to 85km/h with between 1,971 and 2,315 vehicles utilising this section of road on a daily basis (Tweed Shire Council traffic data, T. Fountain pers. comm.). This section of road is densely vegetated for the majority of its length, with poor visibility and no lighting during night hours. “Koala blackspot” signs are in place in the eastern section of the road. The surrounding vegetation and tenure limit the options for ameliorative measures in this blackspot, however a reduction in vehicle speeds is necessary.

Round Mountain Road/Kanes Road

Round Mountain Rd runs for 6.2km from the Pacific Highway east to Tweed Coast Road through Round Mountain. Kanes Rd joins Round Mountain Rd 1.8km east of the highway, and runs southwest for 2.1km to intersect the Pacific Highway to the south. Thirty six koala records are present from the vicinity of Round Mountain Rd, with a further 20 records from the vicinity of Kanes Rd. From its intersection with Tweed Coast Road, Round Mountain Rd passes through approximately 1.7km of Primary, Secondary A and Secondary B habitat which abuts the road on both sides. The road then runs adjacent to Primary and Secondary A habitat to its south for a further 1km. The remainder of Round Mountain Rd and Kanes Rd pass predominantly through cleared lands with patchy occurrences of Secondary B and Other habitat adjacent to the road. Thus, it is the eastern-most 2.7km of Round Mountain Rd that warrants the majority of focus for amelioration of koala road strike issues. This section of road passes through an area of good vegetation connectivity between the central mapped source population cell to the north and Koala Beach to the south.

Traffic speed and volume data collected over the last six years at the far eastern end of the road, where the statutory speed limit is 80km/h, indicate that 407-524 vehicles per day travel in this area at an average speed of 63-65km/h (Tweed Shire Council traffic data, T. Fountain pers. comm.), however the majority of the road is signed with “Drive to suit conditions”, with the condition of the road towards the eastern end easily enabling speeds up to and above 100km/h. No lighting or signage warning of the presence of koalas is present on Round Mountain Rd.

Pottsville Road

Pottsville Road is 6.5km in length, running from the Pacific Highway at Warwick Park north to its intersection with Cudgera Creek Rd before turning east towards Pottsville north of the Pottsville Wetlands. In the immediate vicinity of Pottsville Road, 22 records of koalas are present, predominantly in two areas; north of the Kellehers Rd intersection at the western end, and south of Seabreeze Estate in the east. Vegetation cover is sparse along the road, passing through predominantly cleared lands for most of its length, but intersecting a patch of Secondary A habitat at the eastern end and areas of patchy Secondary B habitat at the western end.

Traffic data is available for the vicinity of the Cudgera Creek Rd intersection which has recorded traffic volumes of between 1,335 and 3,390 vehicles per day, with volumes decreasing in the last five years. The average speed travelled in this location was recorded as 77km/h in March 2010 (Tweed Shire Council traffic data, T. Fountain pers. comm.). Speed limits on the approach to Pottsville drop from 80km/h at Cudgera Creek Rd to 60km/h at Seabreeze Estate then to 50km/h at Coronation Ave. No warning signage is present along the road, however the vegetation abutting the road in the east provides the only linkage in the locality for provision of north-south connectivity. Thus, any provision for ameliorative measures should be at this location where the road passes through potential koala habitat for a distance of 600-700m. Consideration should also be given to options for vehicle calming in the vicinity of the Kellehers Rd intersection where traffic volumes are expected to increase following development in the area.

Tweed Coast Road

Three ‘clusters’ of koala records occur in the vicinity of Tweed Coast Road, from where to where along a stretch of approximately 23.6km. Eight records occur at Chinderah over a distance of approximately 1km, where the road passes through mostly cleared lands, with small patches of Primary and Secondary A habitat adjacent. Only one of the koala records in this vicinity is recent (2009), being an animal that was euthanased following a vehicle collision. Given the amount of habitat remaining, it is unlikely that a large number of animals remain in this area, while reasonable visibility and a statutory speed limit of 60km/h may warrant a lower priority for this blackspot.

A cluster of 12 records at Cudgen, between Kings Forest and Casuarina coincides with the road passing through a vegetated area consisting of Primary and Secondary A habitat, adjacent to the road on both sides, and adjoining Cudgen NR. Traffic data from south of this location indicates high traffic volumes, the most recent count being 9,954 vehicles per day. The statutory speed limit in this section is 80km/h, while vehicle speeds of between 86 and 89km/h on average have been recorded (Tweed Shire Council traffic data, T. Fountain pers. comm.).

The known occupancy by koalas, proximity of vegetation and high speeds in the Cudgen area combine to highlight this area as a major area of concern for vehicle strike on the Tweed Coast Road. Adjacent vegetation cover reduces visibility and increases the likelihood of animals being hit whilst traversing the road. Despite the installation of fauna exclusion fencing and an underpass in the area, their efficacy is likely to be limited due to a lack of maintenance and associated issues. The addressing of these issues and/or investigation into further ameliorative measures in this location is warranted.

A further six records are clustered in and around the urban area of Cabarita. This cluster occurs immediately east of the central mapped source population cell. Small patches of Secondary A habitat occur on the eastern side of the road in this location, thus animals potentially disperse east from this cell; it is expected that low statutory speed limits and good visibility through this urban area currently contribute to a low probability of motor vehicle strike, with koala sightings in this area predominantly resulting from higher human population density rather than high frequency of road strike.

Pacific Highway

Koala records are scattered along the length of the pacific highway on the western boundary of the study area, including seven known mortalities due to road strike between 1982 and 2008. A cluster of 10 records is located in the vicinity of the highway at and around the intersection with Pottsville Road/Sleepy Hollow, which is a known hotspot for koala mortality. In this locality there are a number of areas where vegetation occurs adjacent to the highway, consisting of Secondary B habitat on the western side of the Highway, with Cudgera Creek NR located adjacent, on the western side of the highway. A number of options exist for koalas and other fauna to traverse the highway in this locality: Sleepy Hollow Rd passes under the highway, coinciding with Sheens Creek drainage line, and an additional drainage line to the south provide potential opportunities for under-highway traversal. A land bridge is also located at “Taggets Hill”, with the intent of providing over-highway movement corridor along the ridgeline. This area warrants urgent attention as a priority for the retro-fitting of exclusion fencing and/or other ameliorative measures that could work to reduce the current extent of koala mortalities that continue to be recorded.

Two fauna underpasses are located south of Eviron Road, for which fauna exclusion fencing is in place, along with minimal associated tree plantings. Koala use has been recorded at the northernmost of these underpasses. Additional opportunities for highway traversal occur at the Reserve Creek and Christies Creek drainage lines, where the provision of east-west connectivity would benefit koala populations in the Tanglewood/Round Mountain area; however no associated planting or fencing is in place.

In most of the above cases, a lack of corresponding vegetation on the eastern and often the western side of the highway and a lack of associated fauna exclusion fencing currently limits their utility for koala and other fauna movement. Retro-fitting of fauna exclusion fencing and the establishment of vegetated corridors extending to known koala population cells and large bushland patches from at least those areas identified above is regarded as necessary for provision of east-west connectivity throughout and across the western boundary of the study area.

4. Dogs

Dog attack continues to be recognised as a key threat to koala populations and a significant contributor to anthropogenically-originating koala mortality (Qld EPA 2006; DECC 2008). The impact of dog attack on koala populations increases with increased urbanisation and fragmentation. A higher frequency of cleared areas and roads means individual koalas are required to travel greater distances in order to continue to access resources, increasing the amount of time spent on the ground and thus susceptible to dog attack. Coupled with the increase in density of dogs, the threat to koalas in an increasingly urbanised landscape heightens rapidly.

The record of reported incidence of koala mortality due to dog attack on the Tweed Coast is incomplete, with available records indicating three mortalities over the last 20 years, while the actual number is almost certainly higher. Data from elsewhere however can effectively illustrate the magnitude of the threat, attacks by domestic dogs constituting approximately 15% of all admissions to the Port Macquarie Koala Hospital (Cheyne Flanagan, pers comm.). Data from southeast Queensland indicates around 110 mortalities per year, the threat being ranked as the third most important in this region (DERM 2009) and fourth in NSW (DECC 2008).

Due to the largely rural nature of the Tweed Coast, it is expected that dog attack when it occurs goes largely unreported, with attacks occurring predominantly at night and in bushland remnants not regularly frequented by people. Dog attack should be considered a significant contributor to the suite of threats to the viability of koala populations on the Tweed Coast, thus effort should be applied during the preparation of a CKPoM to effectively reduce this risk wherever possible.

5. Disease

Disease is a fundamental element of wildlife population dynamics and is generally recognised as a density dependent mechanism enacting population regulation. This is also the case with koalas; reproductive output/population size is primarily affected by elevated levels of Chlamydiosis in response to reduced levels of metabolic/genetic fitness and/or immunological suppression brought about by stressors such as a reduction in the available food resource and/or elevated agonistic interactions. Unfortunately, at the urban-bushland interface such natural stressors are replaced by more anthropogenic catalysts such as habitat loss, dog attack and motor vehicle strike, the consequence of which tends to manifest itself in elevated levels of clinical expression of disease, reduced reproductive output and mortality.

As with all naturally occurring koala populations in eastern Australia, both Chlamydia and Koala retro-virus (KorV) are known to be present in the Tweed Coast koalas, the extent to which they collectively contribute to overall mortality rates being arguably more symptomatic of disturbance than anything else. Thus we do not see disease *per se* as a direct or overriding threat to long-term koala population viability in the TCSA providing that sufficiently large areas of habitat remain so as to effectively buffer key source populations from undue disturbance.

6. Koala care and welfare

Given the above, there is an ongoing requirement for an effective mechanism for managing koala casualties resulting from vehicle strike and dog attack, orphaned animals, the survivors of wildfire and animals suffering from disease.

In NSW wildlife welfare and carer groups are licensed to rescue, hehabilitate and release native fauna under Sections 120, 132C and 127 of the *National Parks and Wildlife Act 1974*. until mid-2007, Tweed Valley Wildlife Carers Inc. were responsible for koala rescue and care on the Tweed Coast. Since then, koala specialists, Friends of the Koala Inc. are the responsible organisation under a local area agreement between the two groups.

Volunteer koala rehabilitators are supported by local veterinarians as well as wildlife veterinary teams at Currumbin Wildlife Sanctuary (Currumbin, Qld) and Australian Wildlife Hospital (Beerwah, Qld).

Initial consultation with Friends of the Koala Inc has identified a number of issues that could be addressed/investigated in order to assist its ongoing operation and improve care for koalas in the region. These issues include increasing community awareness regarding how to recognise when koalas require assistance and what to do in this situation, the role of carers, and the need for ongoing recruitment of active carers in the Tweed. Sourcing of financial and in-kind assistance for equipment and training, along with the establishment of a food tree plantation have also been identified as priorities for koala care. The cost, distance to and availability of veterinary services is also an issue in the Tweed and would benefit from consideration of any opportunities for increasing the efficiency of accessing these services when required.

Part 6

Discussion, conclusion & recommendations

Discussion

The preceding sections serve to provide a comprehensive overview of the ecology and other factors influencing and/or limiting the distribution and abundance of koalas in the TCSA. While there have been a number of earlier studies covering the TLGA (Faulks 1990, AKF 1996, Phillips 2002) this project is the first *systematic* assessment of koala distribution and abundance while it has also benefited from application of a number of assessment techniques not previously available. Thus a framework for moving forward on an informed basis towards more sustainable management of the species within the TCSA now exists. In the following pages we further discuss key outcomes arising from the study before proceeding to a general conclusion and associated prognosis for the Tweed Coast koalas. Recommendations intended to guide Council towards preparation of a CKPoM for the TCSA are also provided.

The historical record

An inherent problem associated with survey data such as historical records is that they are invariably observer biased and do not represent the results of systematic survey effort. Within the TCSA this is evidenced by concentrations of records towards the more heavily (human) populated parts of the TCSA and particularly along major roads, as well as the increase in reporting rates over the last few decades. This aside, the techniques we have used nonetheless have the ability to detect gross changes in range parameters across large geographic areas such as the TLGA, but become limited in their application as assessment areas become smaller in size. Hence, quantitative range parameters such as the *EoO* and *AoO* as determined by analysis of the historical record will invariably tend to underestimate the full extent of change (positive *or* negative). For the same reasons, estimates of occupancy derived from these methods must also be interpreted with caution.

Generational Persistence Analysis demonstrates a long history of occupation by koalas on the Tweed Coast, but as evidenced by the recent decline in reporting rate in localities north of the Tweed River, GPA using historical records is insensitive to changes occurring more rapidly than in the time spanned by one koala generation. Thus the relatively stable picture presented by analysis of historical records south of the Tweed River is likely to have been the case up until recently, but – as demonstrated by the results of field survey – belies what otherwise appears to have been a rapid and recent escalation in the rate of decline over the last generation.

Given the paucity of detail accompanying the majority of historical records, little can be gleaned in terms of unequivocally identifying koala black spots within the TCSA. In contrast, in a review of 53 koala mortalities over the period 1991-2000 held by the Koala Rescue Unit, Phillips (2002) found road-strike contributed to 34% of known deaths, nearly half of which (47%) occurred along Clothiers Creek Road. In part this discrepancy is a consequence of the level of simplicity in record-keeping required for maintenance of public databases, resulting in a loss of informative data. While road-strike data derived from the records is scant and clearly underestimates road mortality, that 22% of historical records can be reliably associated with roads in general indirectly serves to identify such areas based on the simple premise that proximity equates to the potential for road strike. It is this relationship that effectively enables existing and potential koala black spots to be determined with confidence, commencing with the need to recognise that most major east-west arterial roads from Bogangar through to Wooyung are potential koala black spots where they traverse forested areas.

Some of the more recent koala mortalities were recorded along the Pacific Highway between Sleepy Hollow and Crabbes Creek / Wooyung. This data attests to the ongoing barrier effect of the Pacific Highway, despite provision of fencing and underpasses along the route that were specifically intended to facilitate the safe passage of koalas and other wildlife. Moreover, annual monitoring of underpasses has not indicated extensive use by koalas, the data indicating infrequent underpass use by no more than a single koala in the Eviron Rd area several years back (M. Fitzgerald pers. comm.), thus leading to the conclusion that more koalas are being killed on the Pacific Highway than are safely travelling under it. This knowledge has clear implications for future management and the provision of east west linkages connecting the TCSA to more western areas of the TLGA. The provision of connectivity will need to focus more on connecting to areas that enable under-highway or overpass traverses than perhaps on vegetated links leading to the Highway itself as these may ultimately result in even higher levels of koala road-kill.

Field assessment

Consistent with the predictions of McAlpine et al. (2007) koala distribution in the TCSA tends to best coincide with large areas of contiguous forest in the central portion of the study area which as discussed below, currently support the bulk of the area's remaining source population(s). The location and clustering of koala activity recorded during field sampling, specifically in terms of apparent population attrition in the north and south of the study area, directly supports earlier conclusions about declines in *EoO* and *AoO* being greater than that inferred by analysis of historical records. Indeed, the *EoO* estimate of 12,631ha based on field survey is approximately 50% smaller than that inferred by the historical records for the TCSA, while the related *AoO* estimate of 20% based on field survey is approximately 55% smaller than that inferred by historical records analysis. Such a significant discrepancy in outcomes leads to two contradictory hypotheses:

(i) if analysis of historical records is correct, then the TCSA koala population remains widespread and is maintaining optimal habitat occupancy rates, or

(ii) if analysis of the field survey is correct, then the TCSA koala population is in an acute state of decline.

In contrasting the incongruity between outcomes based on the historical records and that obtained by field survey, four possible explanations arise for consideration:

(i) the lack of systematic survey associated with the historical record dataset results in an *over*estimation of key range parameters when subject to analysis,

(ii) the systematic field survey methodology is somehow flawed, resulting in an *under*estimate of key range parameters,

(iii) there has been a recent escalation of mortality or threatening processes that have acted directly upon key range parameters within the timeframe of a single koala generation, or

(iv) various combinations of the above.

In short, our considered opinion tends towards (iii) above as the most probable explanation for such incongruity. The apparent decline in occupancy is further supported by independent data collected in areas surrounding Koala Beach, which has also recorded an approximate 50% decline in areas of significant activity over the last five years (T. Fountain pers. comm). Specifically, we consider stochastic impact from recent fire events to be the major contributor to population attrition, an assertion made all the more plausible by factual data related to both the frequency and extent of wildfire events within key koala habitat areas of the Tweed Coast over the last six years. The effect of fire is also to some extent illustrated by the juxtaposition of mapped fire events and the current extent and location of source populations. The cumulative impact of these fire events is reflected in our field survey such that modelling of activity data obtained from the combination of primary and supplementary field sites has demonstrated that remaining source populations in the TCSA are now restricted to three main localities.

Areas of scattered activity in the north and west of the study area may be a result of population cells too small to be detected using the primary sampling intensity but for which long term viability is unlikely due to small population size, degree of isolation and extent of habitat fragmentation. It is also likely that a proportion of these lower use areas also represent that koala population cohort not permanently associated with resident populations, these being dispersing animals and vagrant individuals; the nature of their ranging behavior resulting in activity levels recorded at sites that do not reach the threshold of resident populations.

While transient koalas ultimately contribute to overall population size, the primary focus of conservation and management efforts must be to maintain residency. Thus it remains that the bulk of the TCSA’s remaining koala population(s) is/are contained within the Kings Forest, Round Mountain and Pottsville localities, wherein and collectively a considered population estimate of approximately 144 koalas reside at a density of 0.14 koalas ha^{-1}. The technical accuracy of the density data driving this estimate is also supported by earlier studies; Phillips and Pereoglou (2004) determined a koala density of 0.18 ± 0.04 koalas ha^{-1} and resulting population estimate of 76 koalas for the Kings Forest area, while it is also concordant with the lower range of that recorded by Phillips (2002) at Old Bogangar and Searanch of 0.14 and 0.17 koalas ha^{-1}, respectively.

Tree preferences and habitat mapping

Habitat assessment surveys for the TCSA have resulted in a useful dataset that contributes substantially to resolving complex issues of habitat utilisation by koalas. The value of the larger data set (e.g. inclusion of data from previous koala habitat studies in the TCSA) has allowed a finer level of analysis to be undertaken than in previous studies such that greater clarity in terms of identifying the factors contributing to the composition of *potential koala habitat* has been achieved.

Analysis was successful in terms of unequivocally identifying the most preferred tree species for koalas in the TCSA. Forest Red Gum and Swamp Mahogany are widely recognised as important koala food tree species in northeastern NSW and southeast Queensland (e.g. Lunney et al*.* 2000; Phillips et al*.* 2000; Phillips 2000b; Smith 2004). However the extent of clearing and development within coastal vegetation communities in the TCSA has reduced the occurrence of communities wherein these species are a dominant component to a number (n = 84) of small, disjunct patches totalling 200ha, the bulk of which is now mostly embedded in or adjoining an expanding urban landscape. A cursory comparison of initial (2000/2001) and updated vegetation mapping (BRS 2008) suggests that the extent of loss of potential koala habitat is an ongoing process with a loss of up to 100ha (2.6%) of potential koala habitat within the study area over the last six years.

Further clarification has also been obtained regarding the role of the preferred food tree species Tallowwood and Grey Gum and the reliance by koalas on larger sized trees where these species are growing on erosional and residual soil landscapes. The end result of these analyses is that the previous classification of communities containing these trees species as Secondary (Class A) by Phillips and Callaghan (1996) has required downgrading to Secondary (Class B) in recognition of the presence of secondary food tree species only and the resulting lower carrying capacity of this habitat.

Conclusion

Despite a history of land clearing and associated habitat fragmentation, the TCSA still supports some relatively large areas of *Eucalyptus* dominated forest and/or woodland which contain PKFTs. The obvious question that arises is whether (or not) koalas have a secure future within the TCSA, to which our qualified response would likely be negative, without determined management. We reiterate that the greater proportion of the TCSA's koala population is now largely restricted to three isolated sub-populations between Bogangar and Pottsville, none of which have a guaranteed future. Outside of these areas small, isolated population outliers that are entirely reliant upon recruitment from the aforementioned sub-populations, survive in an increasingly fragmented habitat matrix that is compartmentalised by road barriers and fragmentation, each with differing levels of threat that range from development pressure at the urban/bushland interface, road strike, ongoing habitat loss and increases in fire frequency and intensity. The cumulative impacts of fire over recent years have now resulted in a reduction in koala numbers and associated occupancy rate that is precarious, especially so given that the population is likely already below the minimum viable population size of approximately 170 individuals (Phillips, unpub. data). Additionally, the incidental mortality rate attributable mostly to motor vehicle strike and rarely reported dog attacks is likely to be already exceeding that which is sustainable at the population level. In short, there are no grounds for complacency and it will only be by effectively managing and recovering the remaining source populations that the whole will be preserved.

Koala conservation should ideally be based not only on scientifically sound assessments in the first instance, but also the application of solid landscape ecology/conservation biology theory. In this context two issues arise. Firstly, there is the matter of area and exactly how much land is required to sustain a free-ranging population in perpetuity. From a koala conservation perspective, an *optimal* occupancy rate is that which sees not all available habitat occupied, but in which there is allowance for population expansion (into currently unoccupied areas) and population contraction in response to stochastic events). Indeed, as evidenced by situations in places such as French Is. (Vic) and Kangaroo Is. (SA), a population existing at high occupancy levels encounters stressors 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); Byron Bay, NSW (Hopkins & Phillips 2010); Port Macquarie, NSW (Phillips and Forsman 2005)) of demographically stable, reproducing koala populations consistently return occupancy rates approximating 50% of the available habitat (Phillips et al. submitted). Conversely, for populations considered endangered such as those in Hawks Nest – Tea Gardens and the south-east forests, occupancy rates have been reported at as low as 16% and 8% respectively (Biolink 2005; Allen and Phillips 2008). While for many this variation in occupancy rate is a novel concept in terms of landscape-scale koala management, it makes ecological sense and thus underpins the need for conservation planning to both recognise *and* make allowance for koala metapopulation contraction and expansion over time in response to ongoing recruitment and/or attrition events.

Based on koala density data detailed in Part 3, we have determined that a minimum area of approximately 2,428ha of reasonably well-connected, high-quality koala habitat is required in order to sustain a minimum viable population of ~170 koalas while also allowing for a minimum occupancy rate of approximately 50% of available habitat. This is not to say that such land must necessarily be “locked up” and forested, only that it be managed sympathetically through appropriate planning. It should be noted that the above minimum area is more than half of the total area of potential koala habitat remaining in the Tweed Coast, and that the cumulative area of well-connected vegetated patches (of all habitat categories) in the central portion of the TCSA currently amount to less than 2,300ha. These habitat areas currently exist in a matrix of differing land tenures, including Nature Reserve, Council reserves, rural lands and areas already identified for development. Thus a range of differing approaches to the management of koala habitat will likely be required, specifics of which must be examined in detail during the preparation of a CKPoM.

Given the above, a population at an occupancy rate of ~14% is clearly in a less-than-optimal position to withstand the pressures of stochastic events, ongoing habitat loss and anthropogenic mortality rates. Indeed, PVA carried out by Phillips et al. 2007 has determined that as little as a 2 – 3% increase in the naturally-occurring mortality rate (as a function of total population size) due to incidental factors such as road mortality, dog attack or the stressors associated with disturbance generally, is sufficient to precipitate decline. Given what is already known about the incidence of road strike in places such as Clothiers Creek Road, and that the current population size is much reduced because of recent fire events, we reiterate that the TCSA's koala population is now in very serious trouble.

The preceding prognosis reinforces not just the need to remove and/or minimise known and potential threatening processes from those areas known to be currently occupied, but also to effectively buffer such areas from further adverse impact, facilitate recovery and accommodate the need for population expansion, as well as ensuring that effective habitat linkages are in place to facilitate ongoing recruitment processes. The isolated nature of the remaining population cells may also require more active management on a short- or medium-term basis in order to ensure their ongoing viability as threats are managed. Clearly, existing land management and planning processes are inadequate for the conservation of koalas on the Tweed Coast and these deficiencies require urgent addressing. It would be a great tragedy should this population succumb to localised extinction. Hence the need for an appropriately informed and framed management response, the key purpose of which must be the identification of opportunities and/or actions to facilitate survival of the population in perpetuity.

Recommendations

It will be important that management actions for the Tweed Coast koalas be prioritised so as to maximise the conservation benefit. By example, we see little value in increasing the amount of habitat within the TCSA if those animals potentially able to occupy it simply become road mortalities or victims of wildfire. Thus a focus on reducing the potential for incidental mortalities through motor vehicle strike becomes an overriding, and perhaps the most urgent management need for koalas within the TCSA. With this in mind, the following recommendations are provided in order to facilitate further discussion and provide focus for the key issues to be tackled by the Koala Advisory Group as it moves towards integration of the outcomes of this study into an informed CKPoM for the TCSA.

1.The management framework

- We advocate identification and designation of one or more (Tweed Coast) Koala Management Areas (KMAs) for the purposes of any future CKPoM, the intent to focus and direct management actions appropriately.
- Current patterns of koala distribution and the effective partitioning of the TCSA by the barrier to dispersal presented by the Tweed River provide the basis for the designation of two separate Koala Management Areas within the current extent of occurrence, while there may be grounds for designation of a third KMA in the south of the TCSA.

Northern KMA

- There is a need to determine what actions (if any) can be enacted north of the Tweed River to avoid what otherwise appears to be a inexorable trajectory towards localised extinction within a timeframe of 5 – 10 years.

Central KMA

- There is a need to consider the localised extinction of koalas south of the Tweed River to be a foreseeable event within the next 2 – 3 decades, sooner if those factors currently impacting upon the population such as fire and unsustainable levels of incidental mortality are not addressed.
- A central KMA should encompass those lands containing currently identified source populations, their associated large habitat blocks, areas of high-quality potential koala habitat and key linkage areas.

- Management actions within the central KMA are to have the highest importance with a focus on maintenance and recovery.
- Conservation effort within the central KMA must be focused on a sufficiently large area of land so as to enable to the maximum extent possible a free-ranging koala population – the number of animals comprising which must exceed the *minimum viable population* size – to survive in perpetuity.

Southern KMA

- A lack of activity recorded during field assessments suggests the absence of a major source population in the southern portion of the TCSA. Large areas of potential koala habitat exist however to the south in the Byron Shire. The KAG should discuss the merit of designation of a southern KMA in this area; at this stage the intent of which would be information gathering in order to identify necessary management actions.

2. *Nomination as an Endangered population*

Independently of the above, we consider that the recent decline in distribution and abundance of koalas on the Tweed Coast in addition to the disjunct nature of their contemporary distribution predisposes the population to a high risk of future extinction in the absence of adequate protection and management. Thus we suggest that the status of the Tweed Coast koala population justifies its nomination as an Endangered Population under the TSC Act and would likely meet the criteria for listing.

3. Mitigation of threatening processes

- There is a need to implement interim protection measures in the intervening period, prior to preparation and adoption of a CKPoM, in order to address the ongoing sequential loss of koala habitat on the Tweed Coast. The preparation of a Tree Preservation Order (TPO) to facilitate the protection of high-quality koala habitat and/or individual preferred koala food trees should be considered by the KAG and Council as a matter of priority.

- We consider there to be an urgent need for development of a coordinated strategic management response to fire on the Tweed Coast, requiring a cooperative approach by the National Parks and Wildlife Service, Council and the Rural Fire Service. The intent of this approach is immediate suppression, rather than control, of fire in the event of any future fire events occurring in the vicinity of the remaining source population(s), and to exclude fire from currently occupied areas for a minimum of 6 – 8 years (i.e. at least one koala generation).

- There is an urgent need for development of measures to effectively minimise the potential for incidental road-strike at blackspots identified herein on major east-west arterial roads between Bogangar and Wooyung, with particular emphasis on the Clothiers Creek and Round Mountain Road areas.

- There is a need for evaluation of existing underpass options along the Pacific Highway that offer greatest potential for safe passage of koalas so as to achieving meaningful east-west connectivity, with particular emphasis on the Sleepy Hollow area where ameliorative measures are also required .

4. Planning considerations

- In the development of the CKPoM's planning provisions, there is a need to not only recognise currently occupied areas as *core koala habitat* and implement management accordingly, but also for areas of adjoining high quality (Primary/Secondary A) koala habitat as well as identified linkage areas to be afforded the highest importance and an equal level of protection.

- There will be a need for adoption of a standard Development Control Plan to ensure that all future developments in the vicinity of the remaining areas of koala habitat and/or any resulting KMA consistently result in implementation of 'best-practice' koala-friendly planning measures.

- In accord with the above we consider that there should also be provision for progressive amendment (where such provisions exist) of any currently approved KPoMs so as to ensure consistency with any adopted DCP and/or CKPoM standard.

- There is a need to support strategic bushland regeneration for areas of koala habitat with a view to infilling existing gaps in canopy cover so as to reduce the extent of habitat fragmentation and invasion by weeds that inhibit natural regeneration.

- In locations such as the Pottsville Wetlands and elsewhere within areas of koala habitat the matter of habitat buffers around existing vegetated areas requires consideration, as does habitat augmentation so as to enact a long-term net increase in koala habitat. Development of offset strategies as well as incentives to encourage landholder participation in these processes will be required during preparation of the CKPoM.

- There is a need to develop “minimum data set” assessment standards to ensure that a high standard of habitat assessment by ecological consultants is maintained and that it is this level of assessment that informs development and future planning on the Tweed Coast.

- There is a need to develop long-term monitoring programs to form part of the CKPoM in order to enable the tracking of the success or otherwise of the above recommendations and the plan and their influence on the status of the Tweed Coast koala population.

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Appendices

Appendix I

Location and activity levels recorded at SAT sites. Datum: GDA

Site	Easting	Northing	Activity Level	Site	Easting	Northing	Activity Level
TC002	550771	6850008	0.00	TC110	548422	6876436	3.85
TC003	552004	6849953	0.00	TC115	554413	6876332	0.00
TC004	553178	6850038	0.00	TC116	555611	6876500	0.00
TC005	549408	6851181	0.00	TC117	546035	6877605	0.00
TC006	550922	6851114	0.00	TC118	547458	6877415	0.00
TC008	553296	6851233	0.00	TC120	549661	6877418	0.00
TC011	551965	6852451	0.00	TC121	550833	6877532	0.00
TC018	554404	6853657	0.00	TC125	555362	6877664	0.00
TC031	554646	6857433	3.85	TC129	548419	6878838	0.00
TC032	552246	6858375	0.00	TC130	550774	6878748	0.00
TC034	554398	6858400	76.92	TC134	555507	6878860	0.00
TC038	554444	6859368	23.33	TC135	545993	6879979	0.00
TC043	554412	6860904	10.71	TC136	547348	6880075	0.00
TC044	555550	6860880	0.00	TC137	548877	6880339	0.00
TC046	551892	6861895	0.00	TC139	550283	6879366	0.00
TC048	554396	6862072	0.00	TC140	551975	6880047	0.00
TC049	555602	6862028	0.00	TC142	554390	6880023	0.00
TC051	552296	6863105	0.00	TC143	555603	6880090	0.00
TC052	553169	6863328	23.33	TC144	545853	6881236	0.00
TC053	554404	6863311	0.00	TC145	546978	6881286	0.00
TC054	555591	6863358	0.00	TC146	548382	6881279	0.00
TC056	551721	6864674	3.57	TC148	550705	6881131	0.00
TC057	553202	6864512	58.82	TC149	551888	6881244	0.00
TC058	554408	6864464	23.33	TC150	553178	6881237	0.00
TC059	555598	6864435	0.00	TC151	554345	6881090	20.00
TC062	553268	6865666	0.00	TC153	545990	6882616	0.00
TC063	554367	6865616	0.00	TC155	548645	6882309	0.00
TC067	553195	6866899	16.67	TC156	549665	6882094	0.00
TC069	555607	6866866	0.00	TC157	550853	6882462	0.00
TC071	552025	6868084	0.00	TC159	553110	6882275	0.00
TC072	553218	6868051	23.33	TC160	554399	6882352	0.00
TC073	554473	6867993	47.62	TC162	546014	6883638	0.00
TC074	555609	6868019	0.00	TC163	547310	6883718	0.00
TC075	550951	6869402	86.67	TC164	548468	6883953	0.00
TC077	553191	6869250	0.00	TC165	549459	6883544	3.57
TC078	554532	6869208	0.00	TC169	554374	6883581	0.00
TC079	555555	6869265	0.00	TC171	547185	6884919	0.00
TC080	550818	6870439	0.00	TC172	548383	6884813	0.00
TC081	551980	6870413	0.00	TC201	553774	6857883	50.00
TC082	553090	6870509	0.00	TC202	554394	6857867	3.85
TC083	554495	6870425	10.00	TC204	554401	6859081	90.91
TC084	555753	6870327	0.00	TC205	553364	6862725	14.29
TC086	551834	6871686	13.79	TC206	553785	6863207	11.11
TC094	555951	6873301	0.00	TC207	552705	6863907	10.00
TC095	556723	6872818	0.00	TC208	553198	6863880	23.33
TC106	554354	6875149	0.00	TC209	553766	6863943	29.03
TC107	555473	6875453	0.00	TC210	554427	6863824	27.59

Site	Easting	Northing	Activity Level	Site	Easting	Northing	Activity Level
TC211	554883	6863822	0.00	TC308	553236	6866017	20.00
TC212	552538	6864489	11.11	TC309	553774	6866212	91.70
TC214	554992	6864440	0.00	TC310	553665	6865792	58.80
TC216	554022	6864992	25.00	TC311	554943	6865628	26.60
TC217	554312	6865041	55.00	TC312	554968	6863223	28.10
TC218	554985	6865046	17.24	TC313	554392	6862660	26.70
TC219	552619	6867408	19.35	TC314	554998	6862642	43.50
TC220	553144	6867396	23.33	TC315	555571	6862641	58.30
TC221	553803	6867481	70.59	TC316	553815	6862039	0.00
TC223	553297	6868597	9.68	TC317	554983	6861992	7.40
TC224	555002	6868615	0.00	TC318	553801	6861444	0.00
TC225	554514	6868457	48.00	TC319	554993	6861521	0.00
TC300	554993	6871049	50.00	TC320	555564	6861434	20.00
TC301	554981	6870413	40.70	TC321	555016	6860923	27.60
TC302	555025	6869832	0.00	TC323	554993	6860244	0.00
TC303	555574	6869996	45.80	TC324	554994	6859664	22.60
TC304	553875	6869353	0.00	TC325	553190	6858059	83.30
TC305	554999	6869231	50.00	TC326	553843	6857253	7.40
TC306	555603	6868613	0.00	TC327	553806	6856627	7.40
TC307	553735	6866574	0.00	TC328	554437	6856674	100.00

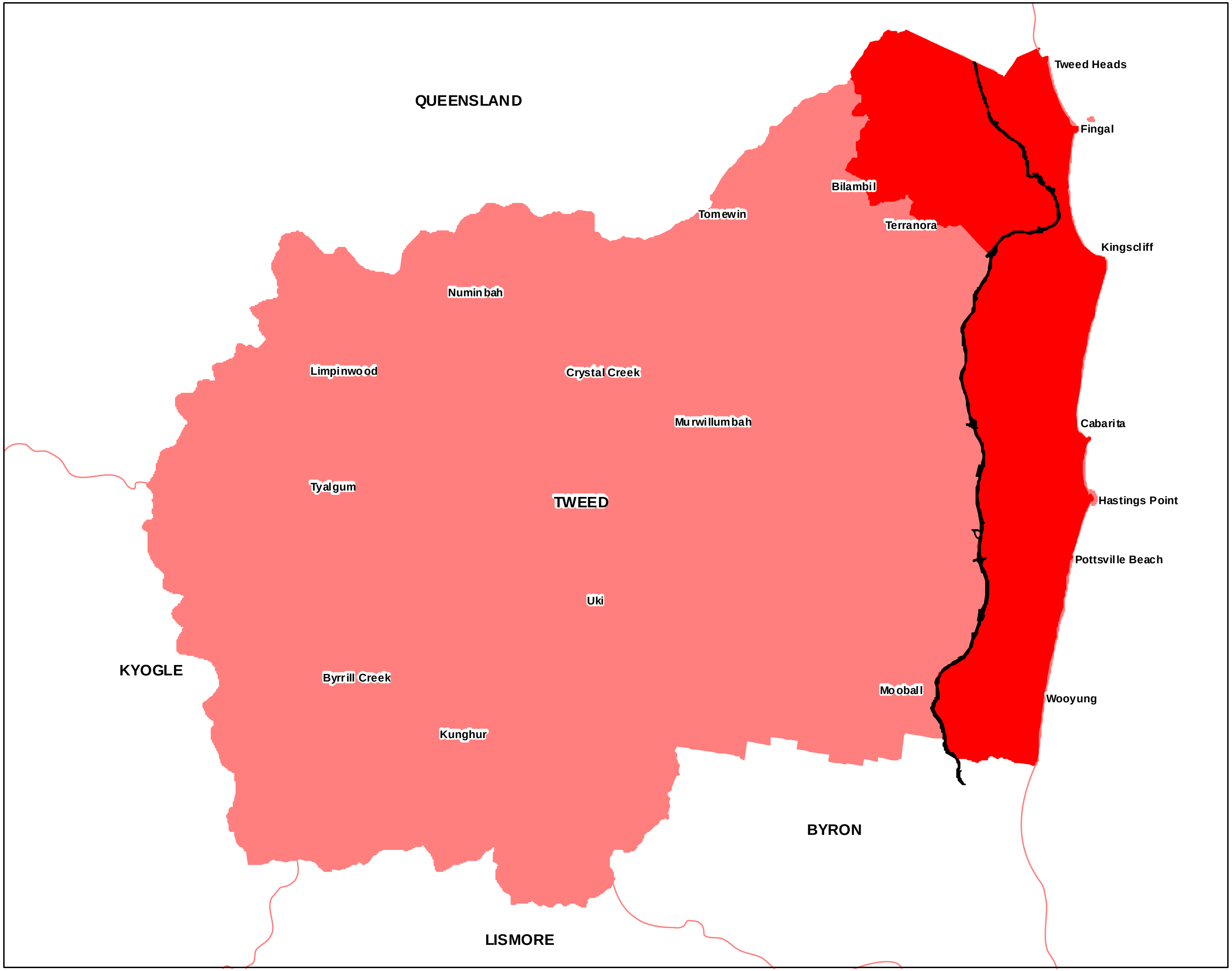
Appendix II

Koala habitat categories

Vegetation communities within the Tweed Coast study area, based on information relating to the floristic composition described and mapped by Kingston et al. (2004). [1]Species present as dominant, co-dominant, subdominant or regular occurrences in vegetation community. *Indicates dominant or co-dominant species associated with vegetation community. [2]Habitat Category: 1 = Primary habitat, 2A = Secondary Class 'A', 2B = Secondary Class 'B', O = Other, U = Unknown. See Section 4 for discussion of significance.

Vegetation code	Vegetation community (Kingston et al. 2004)	Preferred Koala Food Tree species[1]	Cat.[2]	Area (ha)	% of mapped vegetation
101	Littoral Rainforest	-	O	100.06	0.52
102	Sub-tropical / Warm Temperate Rainforest on Bedrock Substrates	-	O	118.90	0.62
103	Dry Rainforest	-	O	1.68	0.01
104	Lowland Rainforest on Floodplain	-	O	55.82	0.29
201	Blackbutt Open Forest Complex	*E. microcorys** *E. propinqua* *E. tereticornis*	2B	976.41	5.10
202	Grey Ironbark / White Mahogany / Grey Gum Open Forest Complex	*E. microcorys** *E. propinqua** *E. tereticornis**	2B	25.73	0.13
205	Sydney Blue Gum Open Forest	*E. microcorys* *E. propinqua*	2B	0.99	0.01
206	Flooded Gum Open Forest	*E. microcorys** *E. propinqua*	2B	5.83	0.03
207	Brush Box Open Forest	*E. microcorys** *E. propinqua*	2B	252.70	1.32
208	Tallowwood Open Forest	*E. microcorys** *E. tereticornis* *E. propinqua*	2B	53.49	0.28
301	Coastal Pink Bloodwood Open Forest to Woodland	*E. robusta* *E. tereticornis*	2A	59.59	0.31
302	Coastal Pink Bloodwood / Brush Box Open Forest to Woodland	-	O	6.27	0.03
303	Coastal Brush Box Open Forest to Woodland	*E. robusta** *E. microcorys* *E. propinqua*	2A	53.96	0.28
304	Coastal Forest Red Gum Open Forest to Woodland	*E. tereticornis** *E. robusta*	1	41.90	0.22
305	Coastal Swamp Mahogany Open Forest to Woodland	*E. robusta** *E. microcorys** *E. tereticornis*	1	153.74	0.80
306	Coastal Scribbly Gum Open Forest to Woodland	*E. robusta* *E. tereticornis*	2A	121.56	0.63
307	Coastal Blackbutt Open Forest to Woodland	*E. microcorys*	2A	13.67	0.07
308	Coastal Tallowwood Open Forest to Woodland	*E. robusta** *E. microcorys**	1	4.55	0.02
309	Coastal Swamp Box	*E. tereticornis**	2A	195.36	1.02

	Open Forest to Woodland	*E. robusta**			
310	Banksia Dry Sclerophyll Open Forest to Shrubland	*E. robusta*	2A	91.11	0.48
311	Coastal Acacia Communities	*E. robusta*	2A	16.09	0.08
312	Black She-oak Low Open Forest to Woodland	-	O	15.76	0.08
313	Cypress Pine Open Forest to Woodland	-	O	28.80	0.15
401	Broad-leaved Paperbark Closed Forest to Woodland	*E. robusta* *E. tereticornis*	2A	1062.30	5.55
402	Broad-leaved Paperbark/Swamp She-oak Closed Forest to Woodland	*E. robusta* *E. tereticornis*	2A	152.92	0.80
403	Broad-leaved Paperbark + Eucalyptus spp. ± Swamp Box Closed Forest to Woodland	*E. robusta* *E. tereticornis*	2A	120.67	0.63
501	Dry Heathland to Shrubland	-	O	77.66	0.41
502	Wet Heathland to Shrubland	-	O	71.12	0.37
601	Swamp She-oak Closed Forest to Woodland	*E. robusta* *E. tereticornis*	2A	412.66	2.15
602	Mangrove Low Closed Forest to Woodland	-	O	421.62	2.20
603	Saltmarsh Communities	-	O	44.74	0.23
701	Sedgeland / Rushland	-	O	229.62	1.20
702	Fernland / Forbland	-	O	57.89	0.30
703	Freshwater Wetlands	-	O	4.97	0.03
801	Foredune Complex	-	O	2.05	0.01
902	Native Grasslands	-	O	25.52	0.13
998	Not Assessed	?	U	541.53	2.83
1001	Mowed Heathland	-	O	6.09	0.03
1002	Early Regrowth Rainforest	-	O	81.87	0.43
1003	Acacia/Other sclerophyll regrowth Open Forest to Woodland	-	O	15.63	0.08
1004	Camphor Laurel Dominant Closed to Open Forest	-	O	391.80	2.05
1005	Native Plantation	-	O	4.13	0.02
1006	Exotic Plantation	-	O	110.05	0.57
1008	Post-mining Regeneration	-	O	477.67	2.49
1009	Unspecified Plantation	-	O	11.39	0.06
1099	Substantially Cleared of Native Vegetation	-	U	12435.93	64.93
			Total potential koala habitat	3815.23	19.93%



TWEED COAST KOALA HABITAT STUDY

LGA boundary

Study area

Pacific Highway

Cadastre and imagery supplied by Tweed Shire Council.

N W E S

0 5 10
Kilometers

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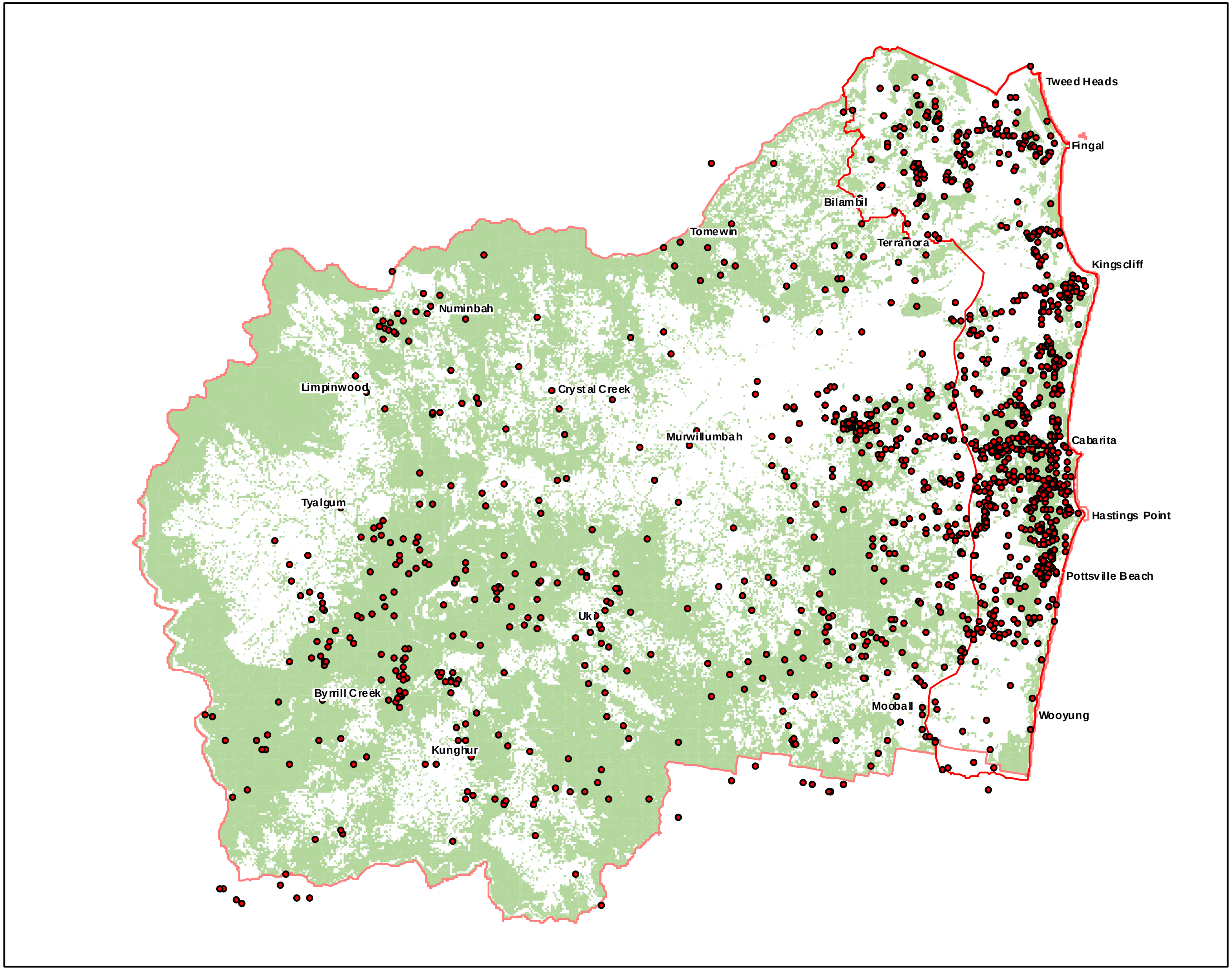
Figure 1.1 Study area



TWEED COAST KOALA HABITAT STUDY

- Koala records
- Study area boundary
- LGA boundary
- Bushland

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N S W E

0 5 10

Kilometers

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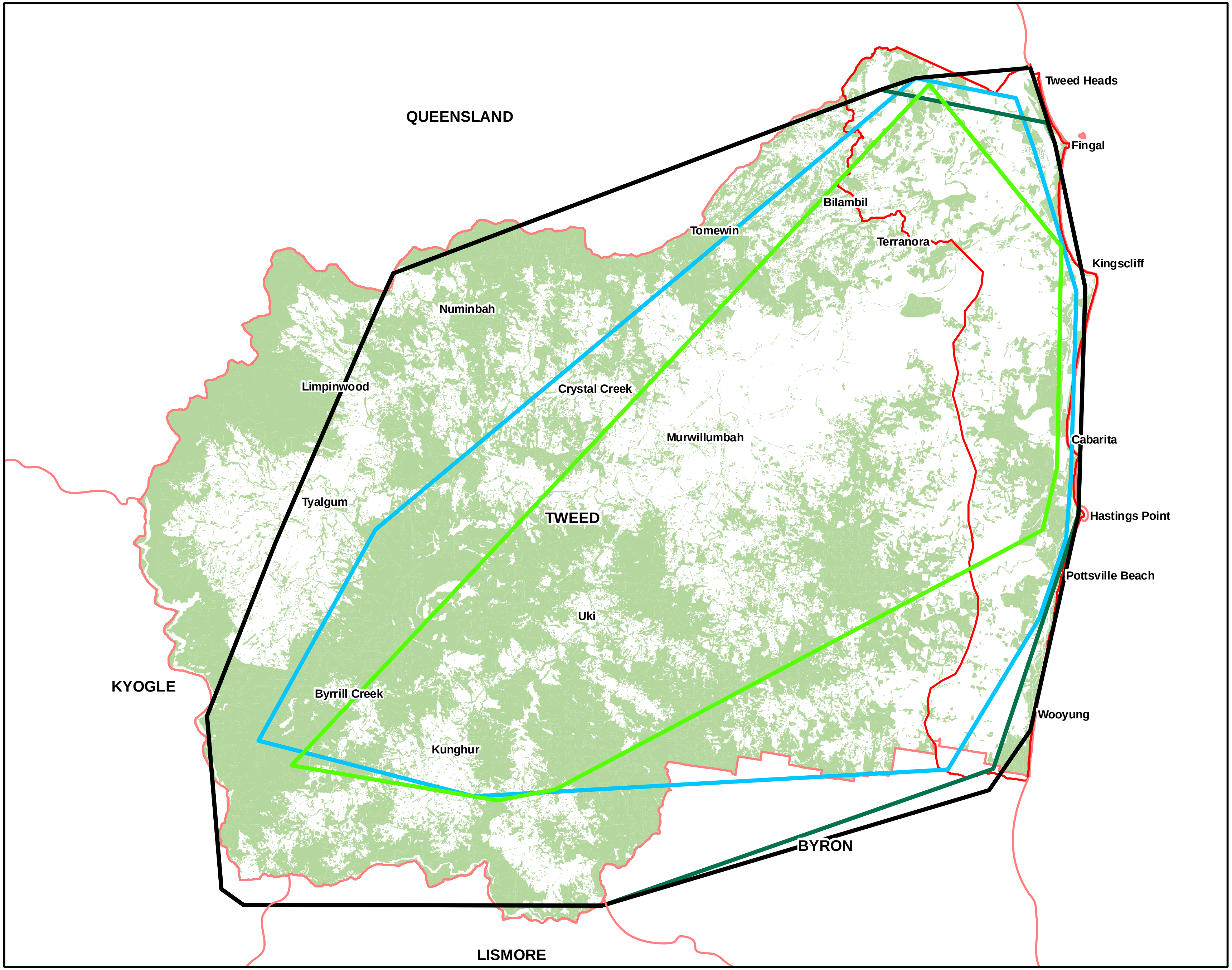
Figure 2.2 Koala records

TWEED COAST KOALA HABITAT STUDY



Extent of Occurrence

- Historic
- 1992-1997
- 1998-2003
- 2004-2009
- Bushland
- Study area boundary
- LGA boundary

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N W E S

0 2.5 5 10
Kilometers

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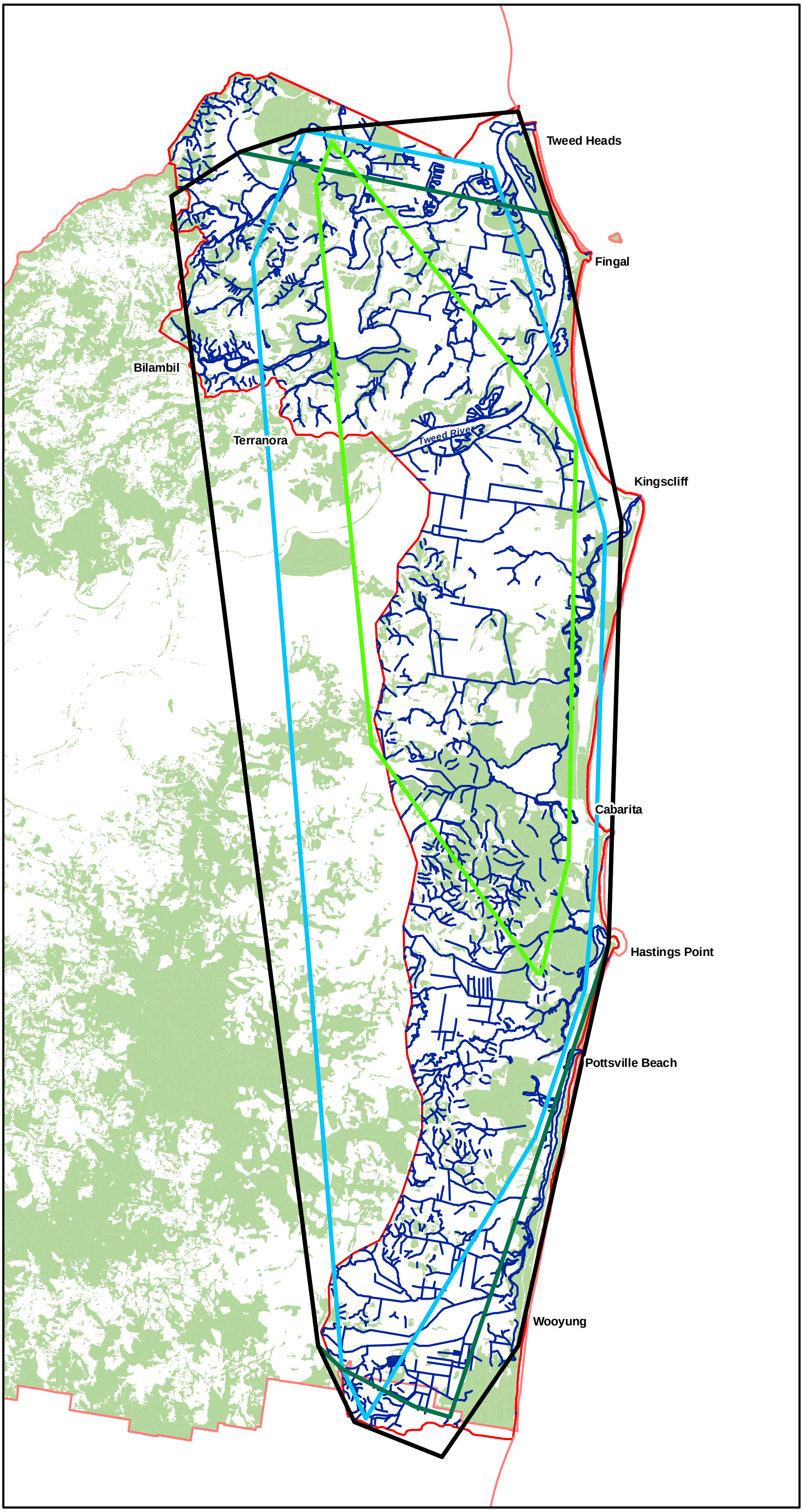
Figure 2.3 Changes in Extent of Occurrence for the Tweed LGA



TWEED COAST KOALA HABITAT STUDY

Extent of occurrence

- Historic
- 1992-1997
- 1998-2003
- 2004-2009
- Bushland
- Waterways
- Study area boundary
- LGA boundary

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N
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0 1 2 4 6
Kilometers

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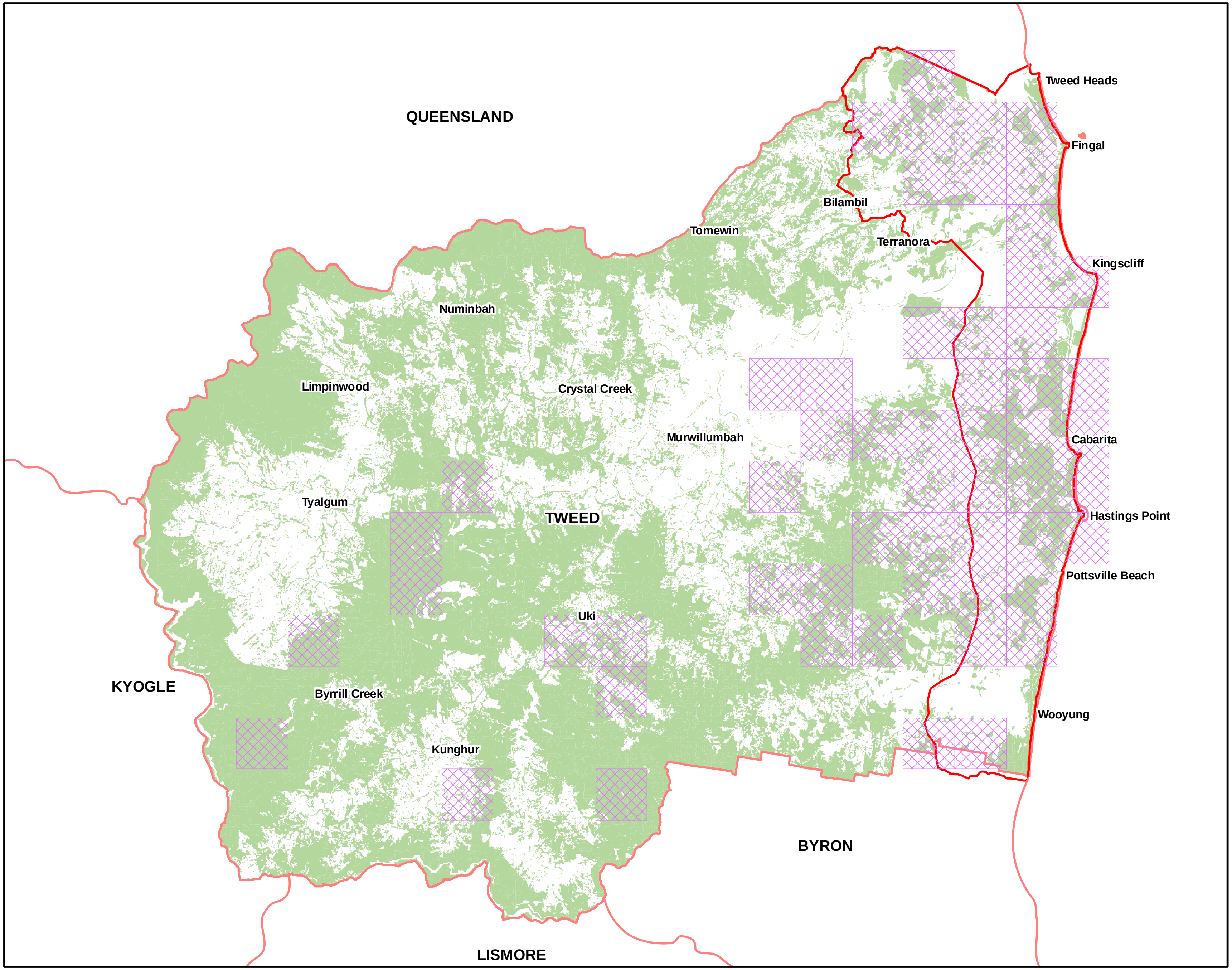
Figure 2.4 Changes in Extent of Occurrence for the Tweed Coast study area

TWEED COAST KOALA HABITAT STUDY



Generational persistence

Bushland

Study area boundary

LGA boundary

Cadastre and imagery supplied by Tweed Shire Council.

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0 2.5 5 10
Kilometers

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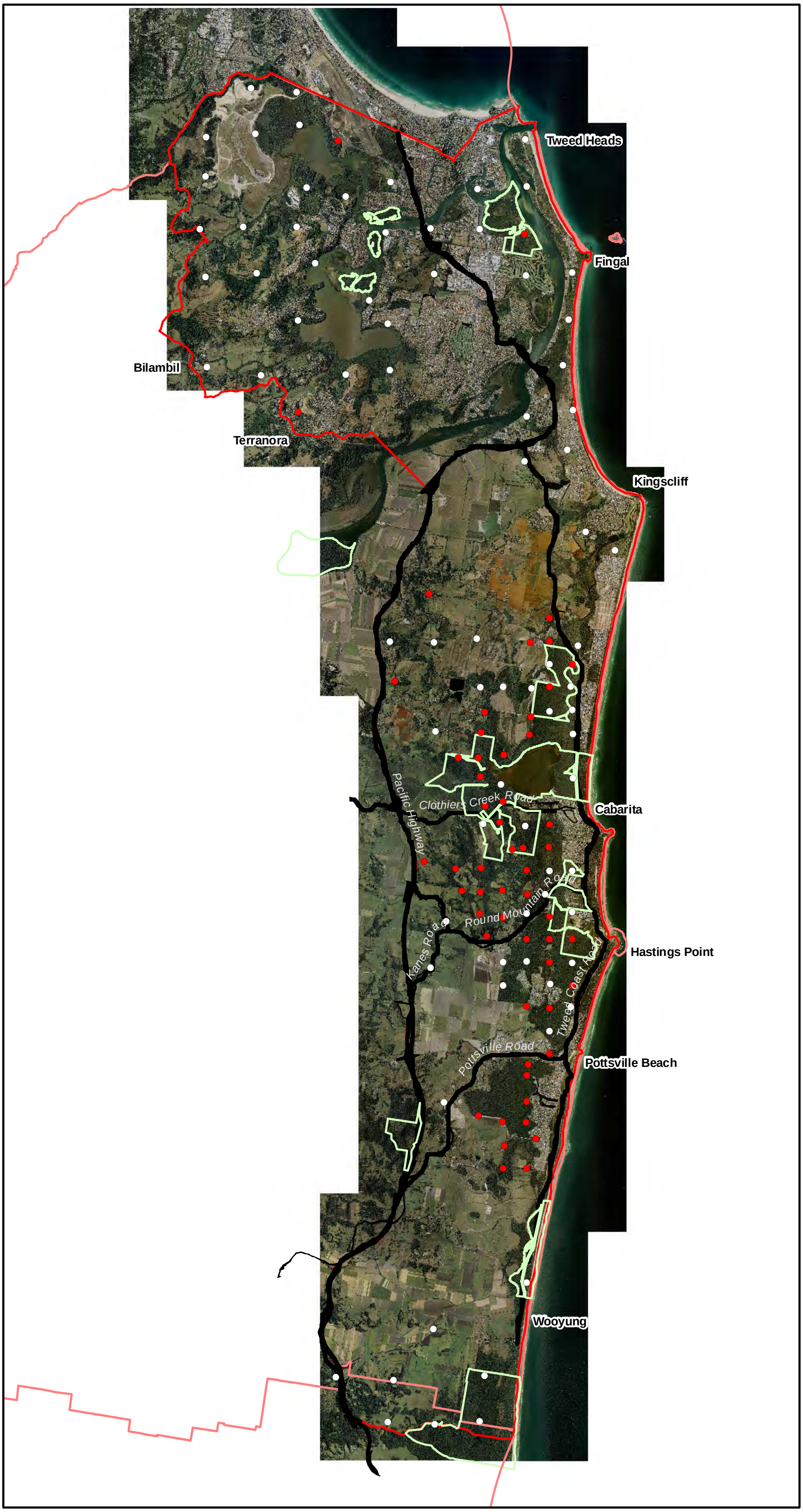
Figure 2.5 Areas of generational persistence for the Tweed LGA



TWEED COAST KOALA HABITAT STUDY

Field sites
- Active
- Inactive

Major roads

Study area boundary

LGA boundary

Nature Reserve

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N
W E
S

0 1 2 4 6

Kilometers

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Figure 3.1 Location of active and inactive field sites

TWEED COAST KOALA HABITAT STUDY

Metapopulation boundaries
Significant activity
High activity
Undefined boundary

Koala sighting

Field sites
Active
Inactive

Major roads

Property boundary

Study area boundary

LGA boundary

Nature Reserve

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Kilometers

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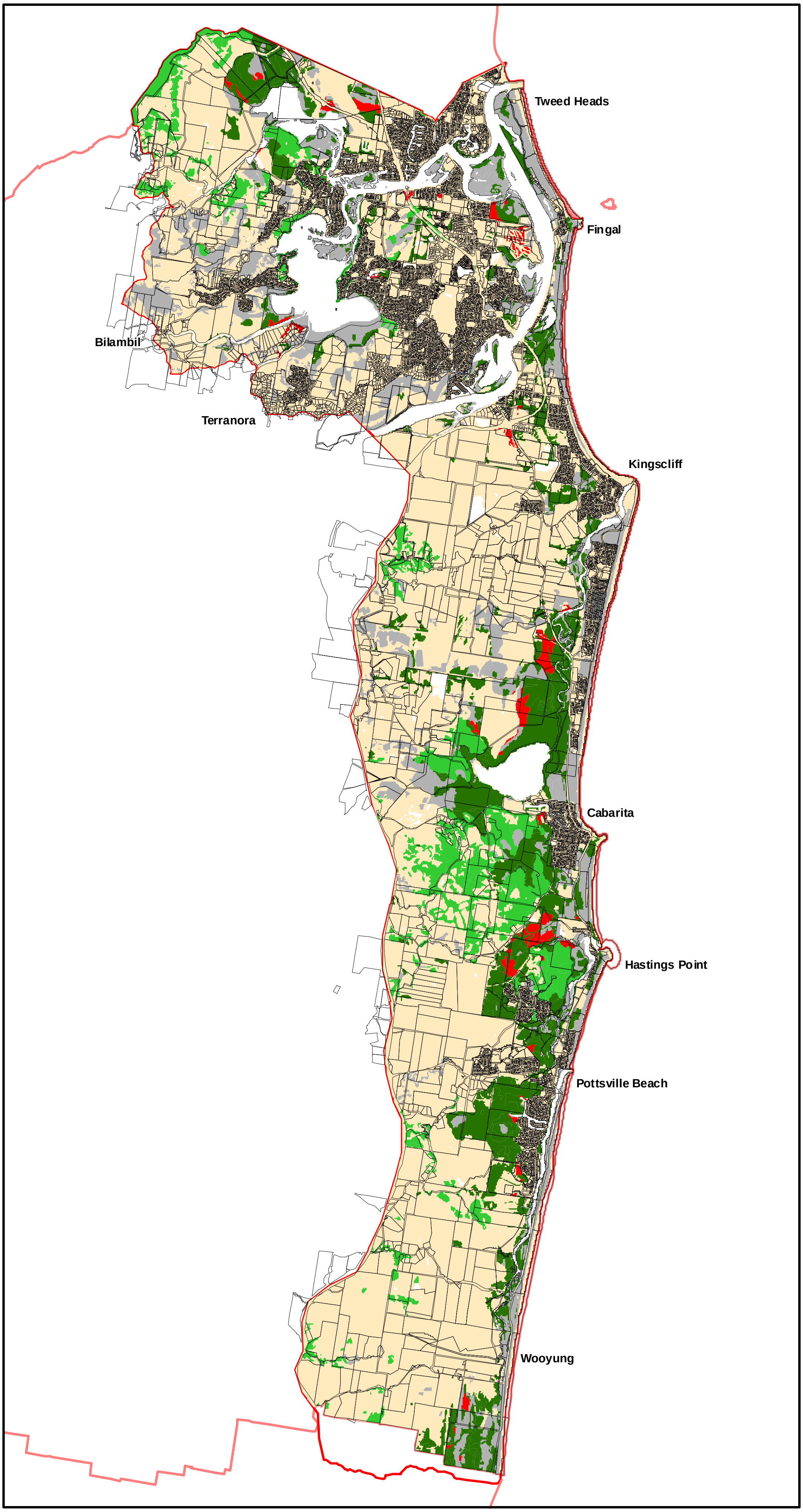
Figure 3.2 Indicative metapopulation boundaries (source populations)

TWEED COAST KOALA HABITAT STUDY



Habitat category
- Primary
- Secondary (A)
- Secondary (B)
- Other
- Unknown
- Property/Road boundary
- Study area boundary
- LGA boundary

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0 1 2 4 6
Kilometers

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Figure 4.5 Potential koala habitat map

TWEED COAST KOALA HABITAT STUDY

Linkages

Metapopulation boundaries

Significant activity

High activity

Undefined boundary

Major roads

Property boundary

Study area boundary

LGA boundary

Nature Reserve

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0 0.5 1 2

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Figure 5.1 Indicative linkage areas

TWEED COAST KOALA HABITAT STUDY

2009 fire area

2004 fire area

Metapopulation boundaries

- Significant activity
- High activity
- Undefined boundary

Major roads

Property boundary

Study area boundary

LGA boundary

Nature Reserve

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N W E S

0 0.5 1 2

Kilometers

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Figure 5.2 Areas affected by fire in 2009 and 2004 in the Cudgen area

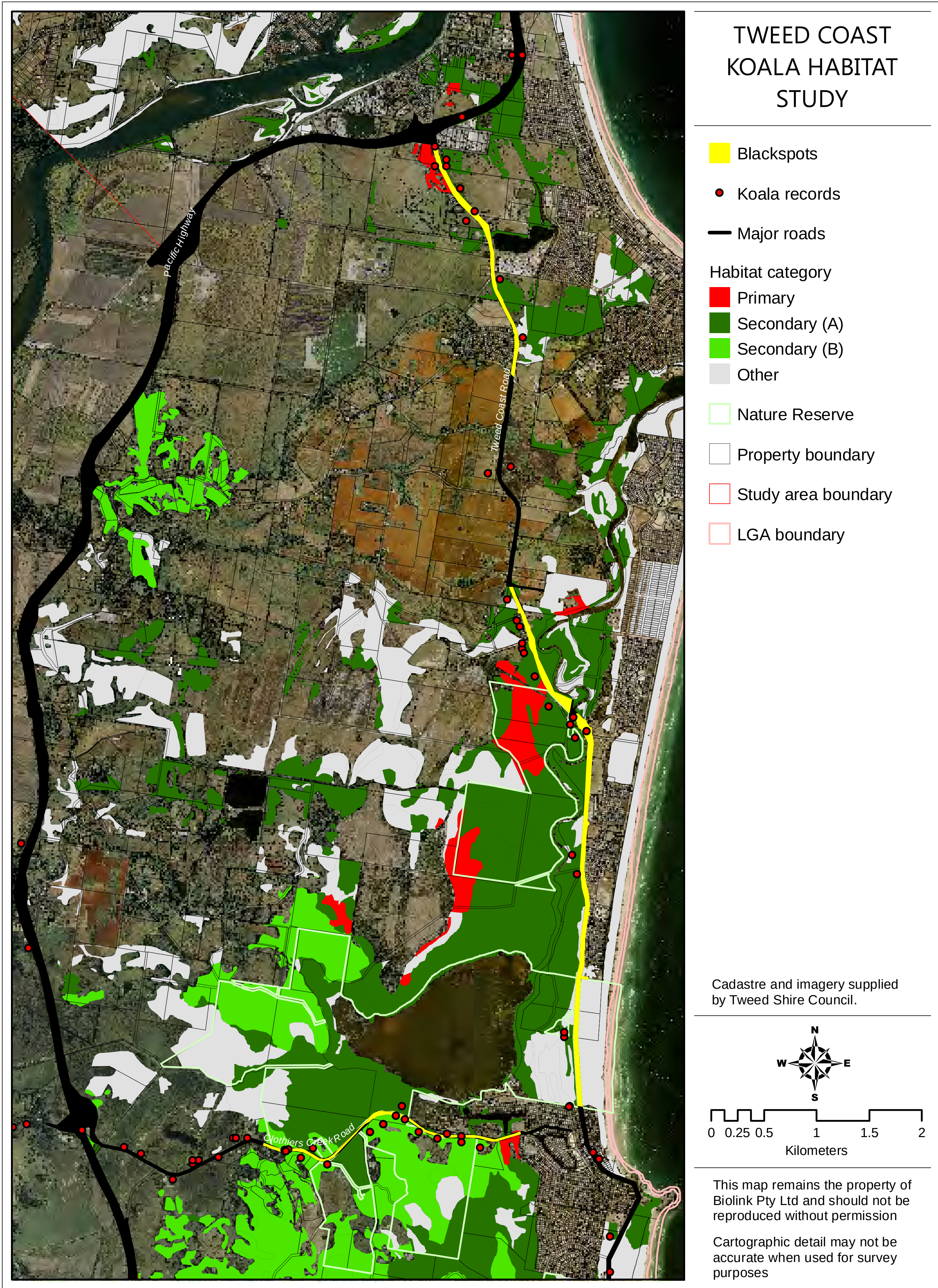

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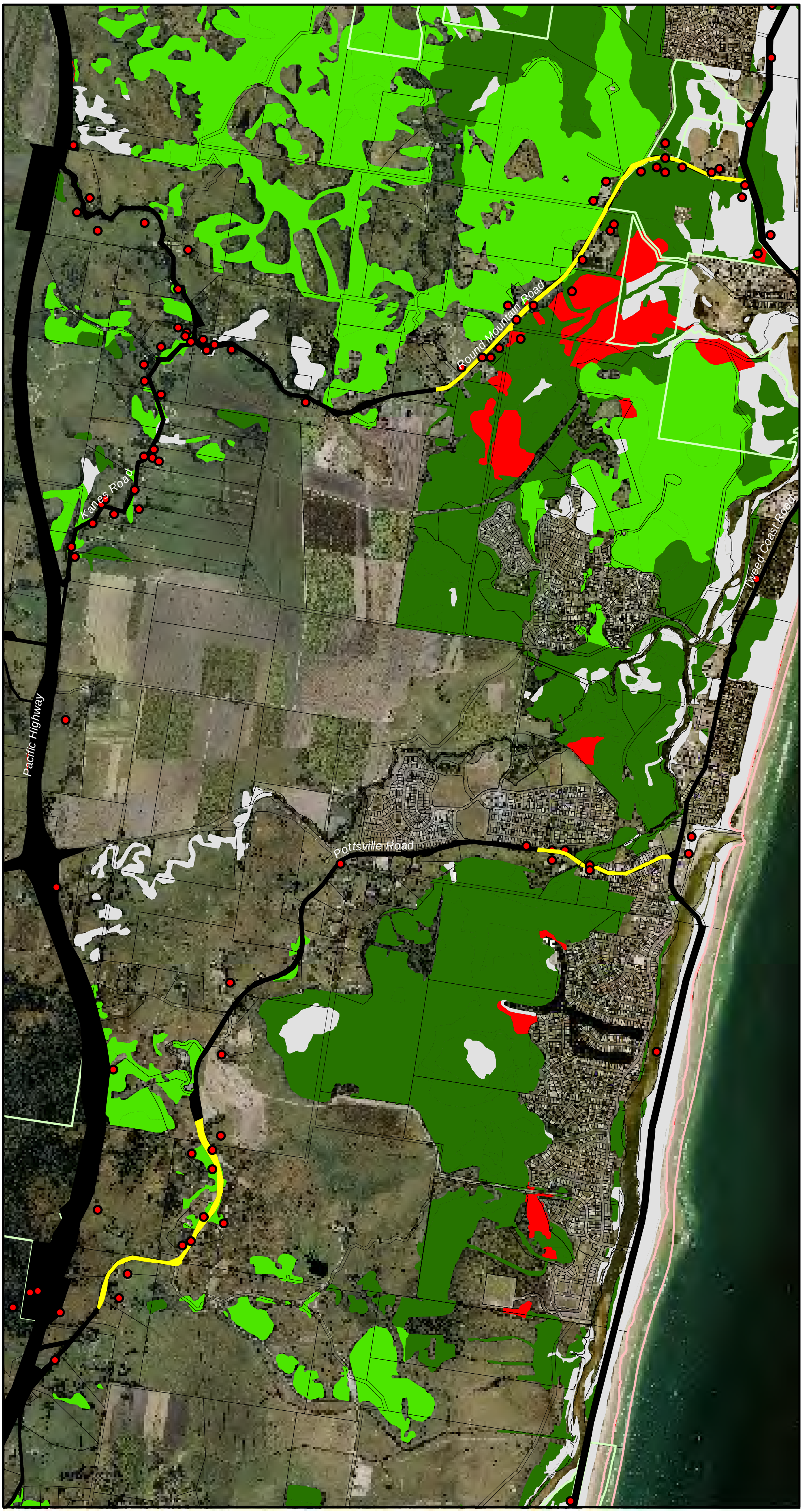
Figure 5.3a Koala mortality blackspots and koala records along major roads



TWEED COAST KOALA HABITAT STUDY

Blackspots
Koala records
Major roads

Habitat category
Primary
Secondary (A)
Secondary (B)
Other

Nature Reserve
Property boundary
Study area boundary
LGA boundary

Cadastre and imagery supplied by Tweed Shire Council.

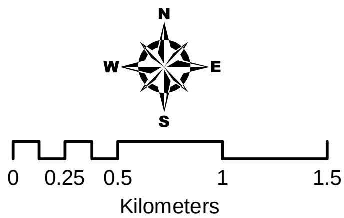


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Figure 5.3b Koala mortality blackspots and koala records along major roads