Koala Habitat & Population Assessment: Ballina Shire Council LGA



Final Report to Ballina Shire Council

November 2013

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Executive Summary

The Ballina Shire Council Local Government Area (LGA) encompasses an area of approximately 49,200ha located between Wardell and Lennox Head on the far-north coast of NSW. This report describes the results of the first shire-wide assessment of koala distribution and abundance for the Ballina LGA.

Analysis of 515 historical koala records for the Ballina LGA confirms that koalas have a history of occupation in the study area that extends back more than a century. Over the last 3 koala generations (1995-2012) and in common with the adjoining Lismore LGA, the records imply an increase in the key range parameter *Extent of Occurrence* from more southern areas of the LGA into farmland on the Alstonville Plateau. For the same time period the records further suggest a significant increase in the associated range parameter *Area of Occupancy* from approximately 46% of available habitat for the time period 1949-1994, to nearly 60% of available habitat. Based on data for the last 6 koala generations covering the time period 1974-2012, historical records for the LGA further indicate the presence of a major source population in the southern section of the study area coinciding with the localities of Bagotville, Meerschaum Vale, Coolgardie and Wardell, with northern outliers in the Uralba and Lynwood areas. Reasons for increases in both the *Extent of Occurrence* and the *Area of Occupancy* are considered to be associated with farming activities on the high nutrient soils formerly occupied by the Big Scrub rainforest, specifically the use of Eucalypts such as Tallowwood for windbreak purposes which has consequently created a habitat matrix now capable of sustaining resident koala populations.

Because of its location, relatively small size and high nutrient soils in more elevated areas, vegetation cover across most of the Ballina LGA is extensively fragmented with high levels of invasion by species such as Camphor Laurel on more fertile soils. Subject to landholder permissions, koala habitat assessments to obtain koala food tree preference, population and occupancy data used a systematic sampling strategy employing the Spot Assessment Technique (SAT) methodology at 1,000m and 500m (supplementary) intervals. Collectively, 123 primary field sites were initially identified for sampling, 56 of which were formally assessed, while a further 19 supplementary field sites were located around primary field sites wherein koala activity had been recorded. Evidence of habitat use by koalas, specifically the presence of koala faecal pellets, was recorded in 18 of the 56 primary field sites which provided a contemporaneous *Area of Occupancy* estimate for the LGA of approximately 32% of available habitat. Significantly, over 70% (13/18) of active primary field sites were located in the aforementioned area between Bagotville, Meerschaum Vale,

Coolgardie and Wardell as well as Uralba and Lynwood. The low contemporaneous occupancy estimate of 32% further implied that a reduction in occupancy rate has occurred over more recent years when considered in the context of that initially estimated across the last three koala generations by historical records analysis alone. Further support of a contemporaneous reduction in the occupancy rate comes from the generally low koala activity levels that were recorded in otherwise suitable areas of habitat. Seven koalas were opportunistically sighted during the course of the field assessment program, including two within the 25m radial searches associated with primary field sites and a third in the associated 1ha line-transect searches. These data imply a mean density of approximately 0.19 koalas ha^{-1} in areas of suitable habitat across the study area.

Data from 2,073 trees sampled during the course of the field assessment assisted in the identification of preferred koala food trees. Consistent with previous work in the Byron and Tweed LGAs to the north, Swamp Mahogany (*Eucalyptus robusta*) and Tallowwood (*E. microcorys*), were confirmed as the tree species most preferred by koalas, while preferential utilisation of Forest Red Gum (*E. tereticornis*) was assumed on the basis of results from other studies. Despite this knowledge, production of a koala habitat map remains contingent upon further information being incorporated into the underlying vegetation mapping layer that informs this aspect of the study. This aside, tree preference data coupled with other knowledge relating to the influence of the soil landscape on tree use by koalas facilitated the development of an independent, hierarchical koala habitat decision tree which enables areas of Primary, Secondary (A) and Secondary (B) koala habitat to be identified. The nature of available vegetation mapping also made it difficult to confidently estimate the number of koalas inhabiting the LGA; however, based on a considered estimate of between 1,500 and 2,000ha of Preferred Koala Habitat being identified, a koala population size estimate of 285 – 380 individuals appears likely, over half of which are likely to occur in the southern section of the LGA.

The currently estimated *Area of Occupancy* by free-ranging koala populations across the LGA is less than the optimal value of approximately 50% of available habitat, while the concentration of a large proportion of the total population in the southern portion of the LGA imposes a measure of vulnerability upon the population as a whole. Major threats to the continued viability of the broader koala meta-population inhabiting the LGA include the current extent of annual koala road-kill on the Pacific and Bruxner Highways (as well as that occurring along the Wardell Road), fire, logging, urban expansion and domestic dog attack. Moreover, a significantly increased threat of road strike mortalities presents itself with the future construction of the Pacific Highway upgrade, specifically at the Wardell bypass which

has the potential to both further fragment habitat and increase koala mortalities within an area now known to contain a nationally significant and key local source population.

Future management of the Ballina LGA's koala populations can be better enacted as a result of the conclusions and associated recommendations arising from this report. These recommendations include the need for an overarching Comprehensive Koala Plan of Management that enables key precincts to be identified for long term management purposes. An "Important Population", as defined for purposes of the Federal Government's *Environmental Protection and Biodiversity Conservation Act 1999,* is considered to occur within the LGA. Standardised development controls and koala habitat assessment protocols, pro-active fire management and controls on the logging of native forests, along with an *a priori* need to assertively deal with the issue of incidental koala mortalities arising from motor vehicle strike and domestic dog attack are also required.

Part 1 - Introduction

1.1 Koala Ecology - A Brief Overview

The koala is Australia's largest arboreal marsupial folivore. Restricted to eastern areas of the Australian continent, the distribution of koalas 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 and/or depending on 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). In areas of northern New South Wales east of the Great Dividing Range, Tallowwood (*Eucalyptus microcorys*), Grey Gum (*E. propinqua*), Forest Red Gum (*E. tereticornis*) and Swamp Mahogany (*E. robusta*) are consistently identified as amongst the most preferred food tree species.

Koalas do not have a high reproductive output; females reach sexual maturity between eighteen months to two years of age, after which they can theoretically produce one offspring each year. However, on average most females in wild populations breed every second year over the term of their reproductive lives (McLean and Handasyde 2006). While examples of free-ranging koalas as old as or older than 15 years of age are known, the longevity of individuals in the wild appears to average 8-10 years for most mainland populations. Phillips (2000a) estimated a generation time for free-ranging koalas of 6.02 ± 1.93 (SD) years, a measure subsequently established as applying to all koala populations in eastern Australia (Threatened Species Scientific Committee (TSSC), 2012 [Conservation Advice]).

The socio-biology of koalas is a critical aspect of the species' management needs yet is overlooked 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 stable breeding aggregation(s) arrange themselves in a matrix of overlapping home range areas (Lee and Martin 1988; Faulks 1990; Mitchell 1990; Kavanagh *et al*. 2007). 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);

and the dissolution of such social structure has been identified as a possible contributing factor to population decline in some areas (Phillips 2000a). Habitat fragmentation can also be a contributing factor to population decline and/or dissolution. Research by McAlpine *et al*. (2005; 2006; 2007) suggests that the chances of koalas being present in an area declines rapidly as the percentage of koala habitat or overall forest cover falls 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 less than 50ha in size (McAlpine *et al*. 2007).

1.2 Threatening Processes

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

- destruction of koala habitat by clearing for urban development, roadwork, public and private native 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 arising from road strike and attacks by domestic dogs;
- mortalities caused by stochastic events such as fire (including high fire frequency for the purposes of fuel reduction).

All of the aforementioned processes already occur in the Ballina Local Government Area (LGA), the impacts of which can become exacerbated through the increased expression of stress related illnesses in resident koala populations which in turn lead to reduced levels of fitness, increased morbidity and an associated decline in reproductive output.

1.3 Conservation & 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 latter listing initiated preparation of a Koala Recovery Plan that was approved by the Minister for Climate Change and the Environment in November 2008. Nationally, a nomination to have the koala listed as Vulnerable for purposes of the Federal Government's *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) was approved by the Federal Minister for Sustainability, Environment, Water, Population and Communities on the 30th

April, 2012, thus adding a further level of protection for the species in Queensland, New South Wales and in the Australian Capital Territory.

The NSW *Environmental Planning and Assessment Act 1979* also provides for the creation of State Environmental Planning Polices (SEPP). Operating within this framework, *SEPP No. 44 (Koala Habitat Protection)* encourages the conservation and management of naturally vegetated areas 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:

" *.. 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*."

Given the preceding context, planning for koalas at the landscape scale should thus endeavour to minimise the potential for adverse impacts by ensuring that:

i) the localities of key source populations are known and being managed in an informed and sustainable manner;

ii) adequate areas of suitable but otherwise unoccupied habitat are being retained so as to enable ongoing processes of population recovery/expansion and contraction to be accommodated over time;

iii) linkages between habitat patches are being provided to assist ongoing processes of recruitment and dispersal; and

iv) the ability of threatening processes to negatively influence i) to iii) above are minimised to the maximum extent possible.

1.4 The Study Area

The Ballina LGA encompasses an area of approximately 49,200ha on the north coast of NSW (Figure 1.1). The LGA is located 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 generally referred to as the Macleay-McPherson Overlap (Burbidge 1960). Eucalypt forests/woodlands, coastal heathlands, wetlands, littoral and sub-tropical rainforest remnants, the latter a relic of the former Big Scrub now largely restricted to areas on the Alstonville Plateau, are representative of the diverse variety of vegetation communities once common across the LGA.

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

1. surveying and analysing current (and past) koala distribution and population size;
2. identifying preferred koala food trees;
3. identifying vegetation and areas considered to be *Preferred* and *Core Koala Habitat* respectively; and
4. assessing key threats to koalas and their habitat.

1.5 Structure of this Report

It is intended that information arising from the preceding investigations will ultimately inform preparation of a Comprehensive Koala Plan of Management (CKPoM) for the Ballina LGA. The report that follows is consequently comprised of a further five parts as follows:

Part 2 provides the results of an analysis of historical koala records for the LGA, thus yielding information on changes in key range parameters and the localities of source populations;

Part 3 details the field survey component of the study and the resulting outcomes in terms of providing contemporary estimates of the current distribution, habitat occupancy rate and number of koalas inhabiting the LGA;

Part 4 examines issues of koala food tree preferences and associated influences of soil landscapes, using the outcomes to derive a decision tree to inform the mapping of areas preferred koala habitat across the LGA;

Part 5 considers threatening processes that operate within the LGA and provides the background for discussion on their mitigation; and

Part 6 concludes with a prognosis and series of recommendations intended to inform the next stage of the overall process towards drafting a CKPoM for the LGA.


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KOALA HABITAT
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LGA Boundary
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Figure 1.1 Ballina LGA Study Area
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Part 2 - Analysis of Historical Koala Records

2.1 Introduction

Analyses of historical fauna records are increasingly being used to inform management and conservation decisions. The koala is an iconic Australian marsupial that has been the focus of one national survey (Phillips 1990), while in NSW three statewide surveys have also occurred (Gall 1978; Reed and Lunney 1990; Lunney *et al*. 2009). Analyses of the data that results from these surveys are increasingly being used to inform planning outcomes at LGA level (Lunney *et al*. 1998; Phillips *et al*. 2007; Phillips *et al*. 2011).

Extent of Occurrence (EoO) and *Area of Occupancy* (AoO) are two key range parameters that relate to the spatial distribution of a given species. The EoO is that area encompassed by the outermost limits of the area within which the species occurs and is most typically represented by a Minimum Convex Polygon. In contrast the AoO is the actual area within the EoO over which the species can be found (Gaston 1997) and is typically enumerated using a grid-cell based approach with occupancy estimated by the total number of occupied grid cells; AoO estimates are therefore sensitive to sampling parameters such as study area and grid cell size. Although more useful, changes in AoO over time are harder to quantify for species such as the koala because and amongst other things, there tends to be an increase in available records over the last two to three decades. This creates the potential for an increase in the probability of a record being present in a given area over more recent years. Thus, using historical records to examine change in quantitative range parameters can potentially misrepresent the full extent of change (positive or negative) if the inherent biases cannot be effectively accommodated.

In this section of the report, analysis of historical koala records for the LGA is undertaken with a view to exploring the following issues:

(i) identifying broad changes/trends in the geographic distribution and habitat occupancy rates of koalas over time; and

(ii) determining the extent to which the historical record may be capable of informing decisions relating to koala conservation by way of identifying important source populations and/or other issues that may assist longer-term management objectives.

2.2 Methods

Koala records were obtained from Ballina Shire Council, NSW Wildlife Atlas and Friends of the Koala (FoK) databases. Once collated, records were sorted chronologically using 6 yearly intervals (*i.e*. a koala generation) progressing backwards from 2012 (*i.e*. Gen 1: 2012-2007; Gen 2: 2006-2001; Gen 3: 2000-1995; Gen 4: 1994-1990 etc). The resulting data set could then be further partitioned to enable comparisons *pre* 1995 and *post* 1994 (the timeframe 1995-2012 covering a period of 18 years to approximate the three most recent koala generations) in order to be able to consider outcomes in the context of standards applied by International, Commonwealth and State-based conservation criteria which *inter alia* place weight on the concept of population change over a time period of three consecutive (taxon-specific) generations.

2.2.1 Extent of Occurrence

The historical EoO for koalas in the LGA was estimated as the area enclosed by a Minimum Convex Polygon (MCP) derived by connecting the outer-most of all koala records over time. Two further MCPs were then determined for comparison purposes, the first encompassing the distribution of koala records across the LGA prior to 1995 (the *pre*-1995 EoO), the second encompassing the distribution of koala records after 1994 (the *post*-1994 EoO) to effectively reflect that of the three most recent koala generations.

2.2.2 Area of Occupancy

A 2.5km x 2.5km (625ha) grid-cell overlay constrained by the historical EoO was created to provide a series of cells for sampling purposes. The 625ha grid-cell size is generally acknowledged (Gordon *et al*. 2006; Phillips *et al.* 2007; Lunney *et al*. 2009) as the minimum area necessary to accommodate spatial uncertainty in the data (*e.g*. use of different mapping datums, observer error etc.). As with the EoO, trends in the AoO were compared between two time periods: *pre*-1995 and *post*-1994. To assist this process fifty percent of the aforementioned grid-cells were randomly selected, the number (proportion) within which koala records were present was considered to represent an estimate of the total area likely to be occupied. This process was repeated 10 times for each of the two time periods being examined. In order to deal with the disproportionately greater number of koala records associated with the *post*-1994 data set, sampling iterations for that time period were based on a single suite of randomly selected records, the number selected being equal to that of the *pre*-1995 data set to which it would be compared. Differences between time periods were tested for homogeneity of variance prior to analysis using two-sample *t*-tests.

2.2.3 Generational Persistence Assessment

Koala records were also examined for re-occurrence in the same area over time. The term Generational Persistence Assessment (GPA) is used to describe this process which examines for the presence of koala records within a localised area over overlapping generational time frames and so identifies the potential presence of important resident and/or source populations. For GPA purposes, "localised" was considered to mean the area defined by the aforementioned 625ha grid-cells wherein generational persistence was established by koala records re-occurring within one or more cells over the course of three or more consecutive koala generations.

2.3 Results

Five hundred and fifteen individual koala records were obtained for the LGA, comprising 295 from the NSW Wildlife Atlas, 196 from the FoK and 24 from the Ballina Shire Council databases respectively. The chronological distribution of these records is illustrated in Figure 2.1, with the extent of their spatial distribution illustrated in Figure 2.2.

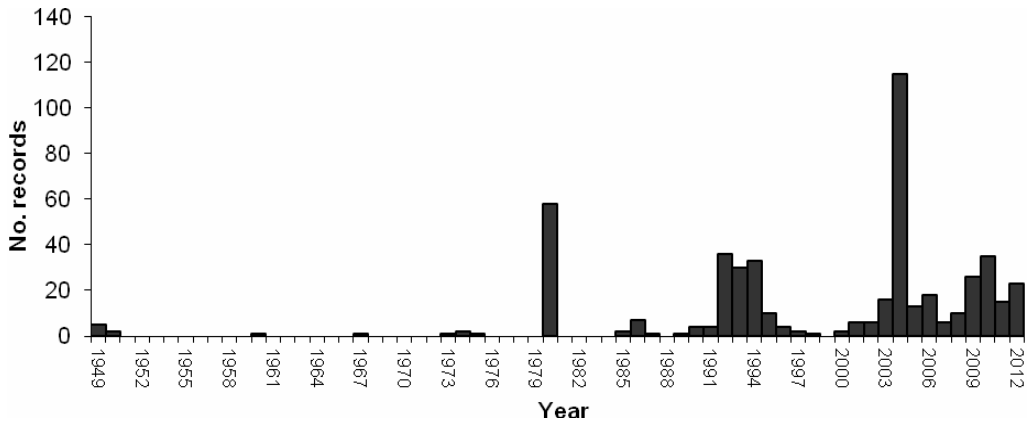


Figure 2.1. Chronological distribution of 515 koala records for the LGA over the period 1949-2012.

Notwithstanding the existence of records dating to 1900 on the southern side of the Richmond River, the earliest publicly-available records of koalas within the LGA were recorded in 1949 & 1950 from the localities of Bagotville, Wardell, Alstonville and Uralba. The frequency of reporting of koala records gathers momentum from the 1980s, this time period coinciding with the first Statewide survey (Gall 1978), thereafter the National Koala Survey (Phillips 1990; Reed and Lunney 1990) and most recently a 2006 community-based survey (Lunney *et al*. 2009). Spikes in the data set between 1979–82 and 2003-06 reflect

the allocation of records arising from State-wide surveys, while those over the three year time period 1992-1994 reflect the substantive individual efforts of Ms. Alison Siliakus and the late Mr. Bill Tubbenhauer from a single property in the Bagotville area. The greater majority of available records over the last two decades have been collated by the Lismore-based Friends of the Koala.

2.3.1 Extent of Occurrence

Available koala records indicate a historical EoO of approximately 43,982ha, this being that area captured by a MCP with vertices that intersect the outer-most koala records in the dataset for the time period 1949-2012. Interestingly, partitioning of the records revealed that this EoO has changed over time. For the time period 1949-1994 the EoO covered an area of 35,464ha, while over the last three koala generations (*i.e*. 1995-2012) the EoO has expanded by approximately 24% to cover an area of 41,042ha. Figure 2.3 illustrates the historical EoO, while Figure 2.4 illustrates EoOs for each of the two key time periods being considered, the associated overlay indicating that the areas where range expansion is most apparent has occurred in the northwest between Pearce's Creek and Newrybar, as well as the area between East Ballina and Skennars Head in the east.

2.3.2 Area of Occupancy

The AoO estimate enabled by the 190 records that comprise the sub-set of data for the time period 1949-1994 was compared to that of 190 randomly selected records for the time period 1995-2012. Randomly sampling 50% of the historical EoO over 10 iterations in both instances returned the following results:

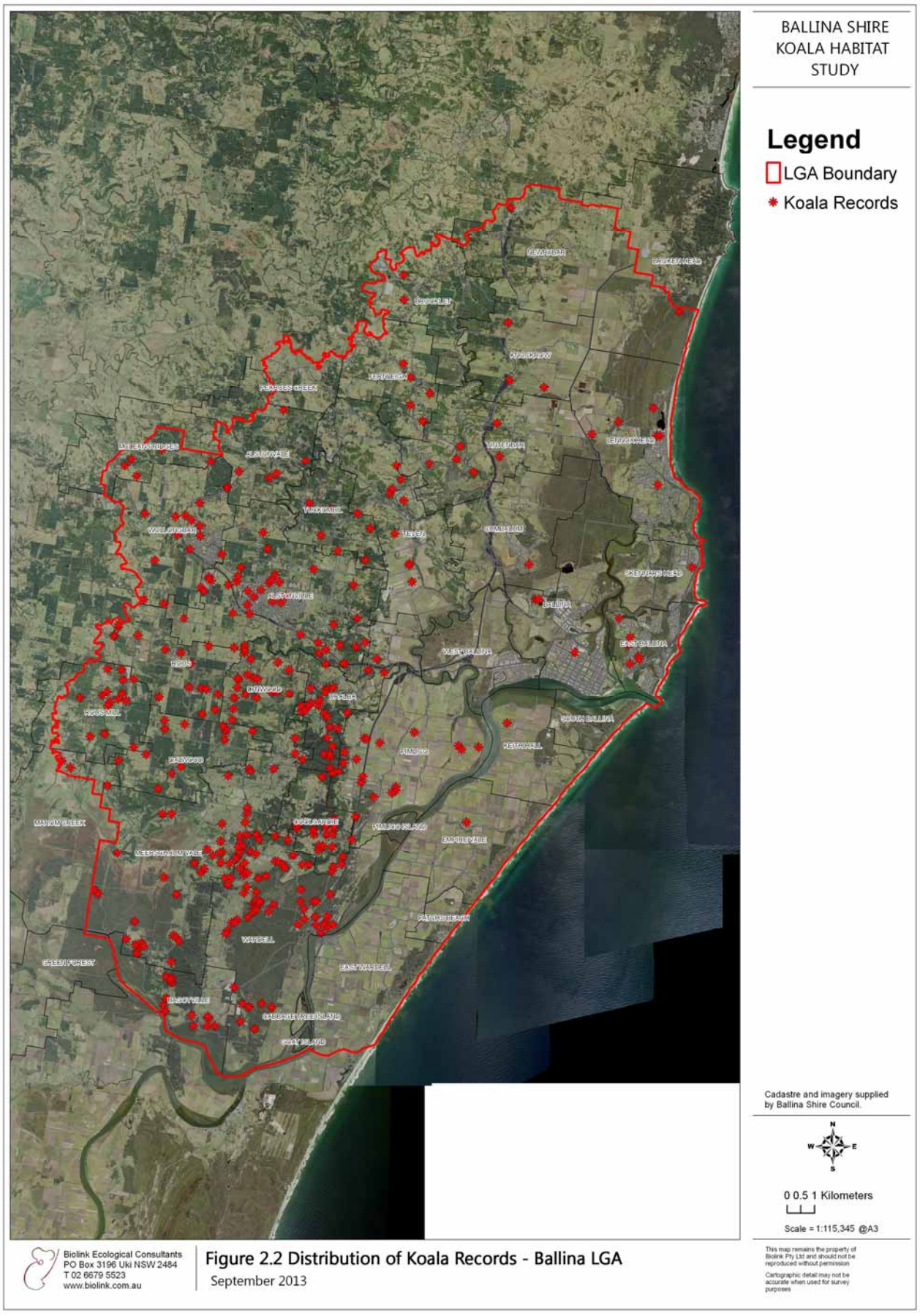
1949-1994

Occupancy estimated at 45.78 ± 1.37% (95% CI) of available habitat.

1995-2012

Occupancy estimated at 58.68 ± 2.18% (95% CI) of available habitat.

Analysis of the data associated with the preceding outcomes implies that there had been a significant increase in the extent of the study area being occupied by koalas over the last three koala generations (t = -5.00634, 18_{df}, P < 0.05, two-tailed test).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Koala Records
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Figure 2.2 Distribution of Koala Records - Ballina LGA
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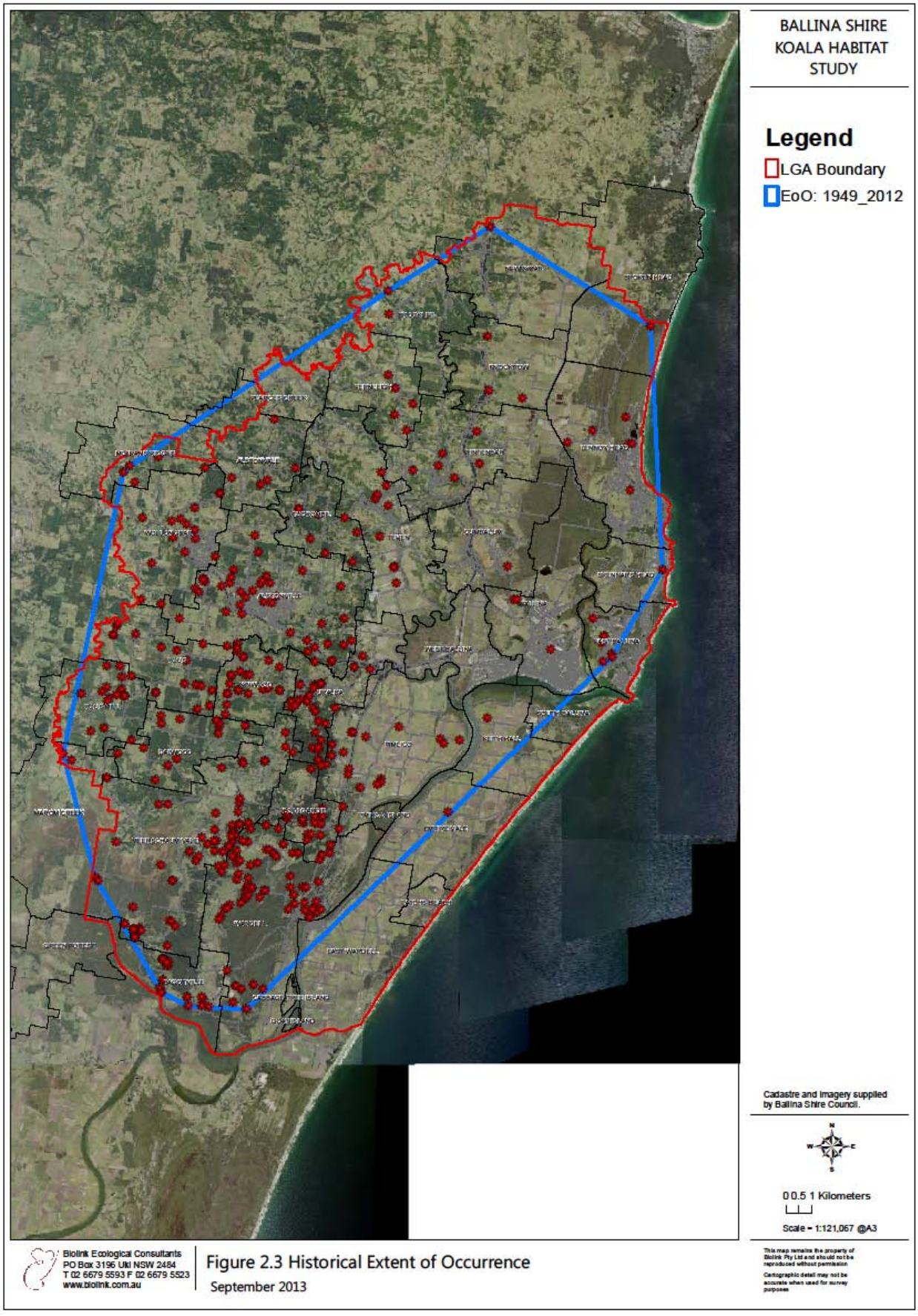
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Figure 2.3 Historical Extent of Occurrence
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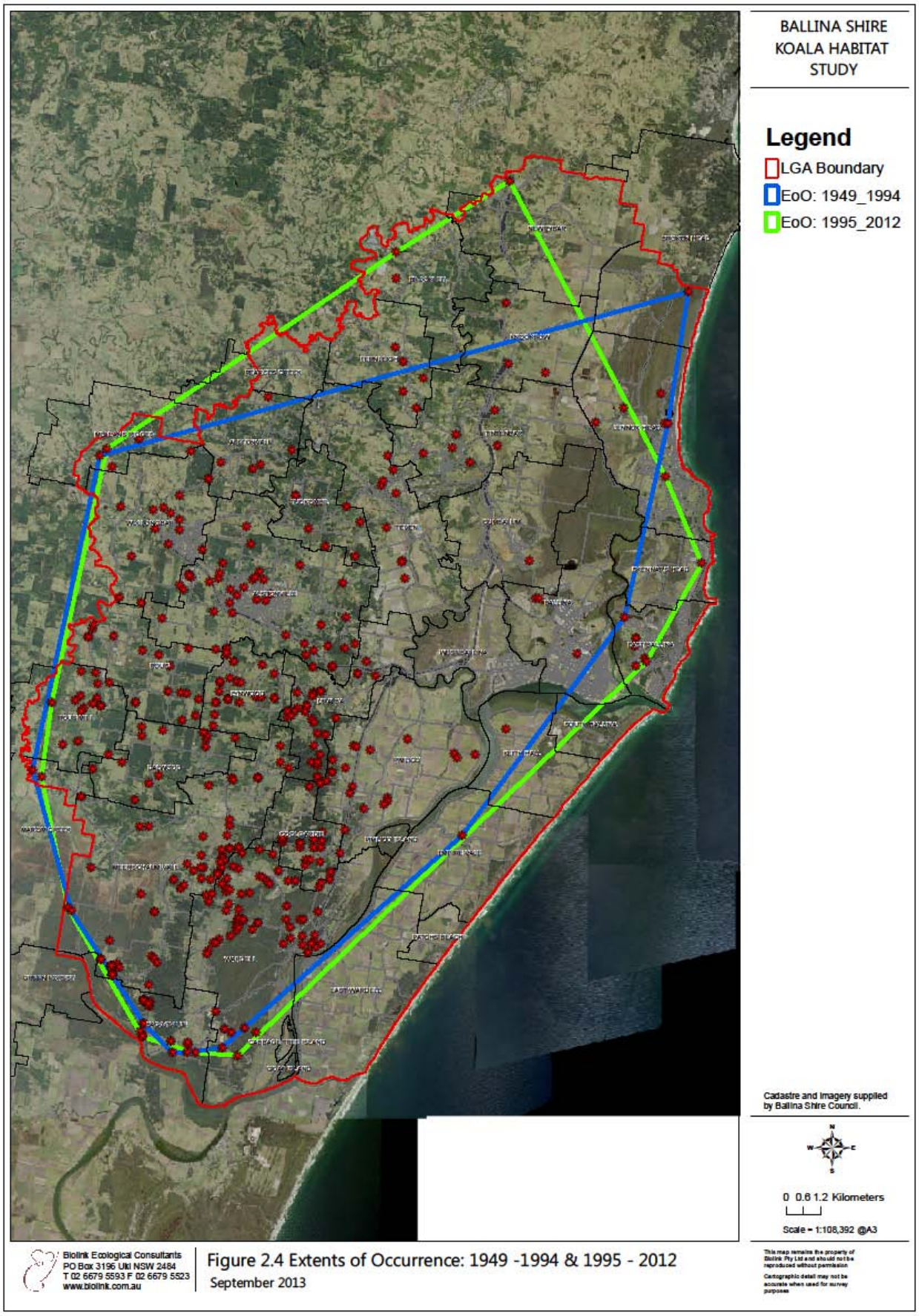
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Figure 2.4 Extents of Occurrence: 1949 -1994 & 1995 - 2012
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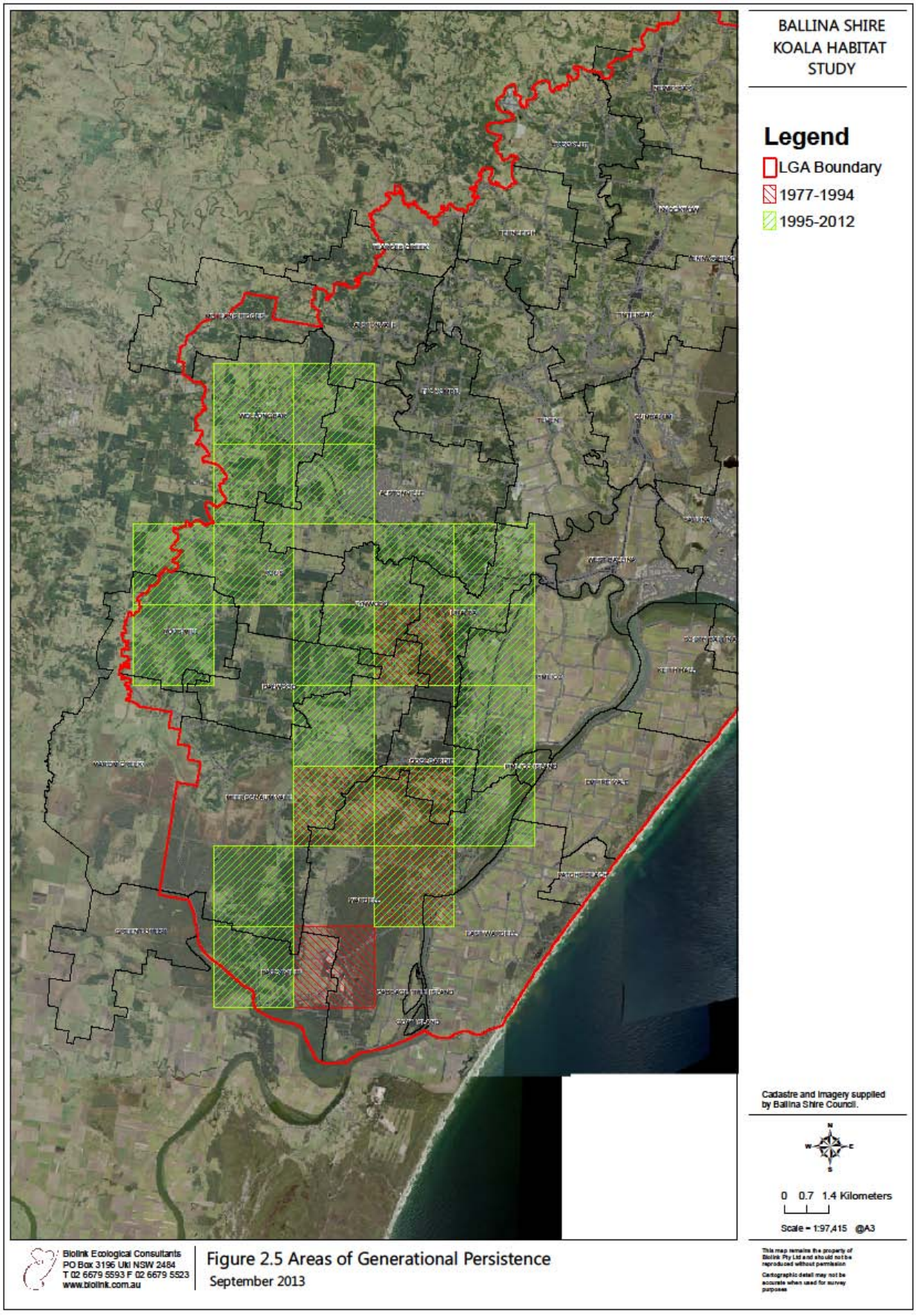
2.3.3 Generational Persistence

During the three koala generations from 1977 to 1994, available records for the LGA indicate a relatively large area of generational persistence generally located in the south of the LGA coinciding with the localities of Coolgardie, Wardell, Bagotville and Meerschaum Vale, along with a smaller outlier in the Uralba/Lynwood area.

The following three-generation subset (years 1995-2012) confirms the continued persistence of the abovementioned source population in the southern half of the LGA, but is otherwise notable for the increase in areas being the subject of persistence. There appears to be two elements to the apparent increase, the first being an expansion centred around the aforementioned areas in the south of the LGA, the second being an expansion to the west in the area from Rous Mill through to Wollongbar. Interestingly, the areas supporting these expansions comprise a highly fragmented landscape consisting mainly of agricultural and rural/residential land use types, with little or no contiguous forest but where the planting of preferred koala food tree species such as Tallowwood has taken place. Figure 2.5 illustrates areas of generational persistence over the preceding 6 koala consecutive generations 1977-1994 and 1995-2012.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1977-1994
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Figure 2.5 Areas of Generational Persistence
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2.4 Key Outcomes

- The historical record indicates that koalas have a long history of occupation in the Ballina LGA, with the earliest known record dating back to 1900 from the southern banks of the Richmond River.
- The historical *Extent of Occurrence* of koalas in the Ballina LGA encapsulates almost the entire LGA with the possible exception of small areas to the east of the Richmond River in the southeast. Records further imply a significant expansion of the EoO over the last three koala generations, the trend most noticeable in the northwest and in the vicinity of East Ballina.
- *Area of Occupancy* analysis for the time period 1949-1994 implies an optimal occupancy rate approximating 50% of available habitat which appears to have further increased over the last 3 koala generations.
- Generational Persistence Assessment alludes to a significant expansion in the amount of habitat exhibiting generational persistence over the last three koala generations. Assessment further supports the presence of a major source population in the southern half of the LGA, the data establishing persistence over at least 6 consecutive koala generations in the southeast.
- Documented range expansions and GPA increases by koalas across the LGA? indicate the presence of suitable habitat within a highly fragmented matrix. To this end the presence of preferred food trees such as Tallowwood in agricultural windrows amidst plantations have become critical habitat elements, more so because they are also growing on high nutrient soil landscape types.

Part 3 - Field Survey

3.1 Introduction

Accurately determining the contemporary distribution of koala populations across the landscape is a necessary pre-requisite for informing koala population conservation and/or management programs. Standard approaches to addressing issues of koala distribution at the macro-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 (*e.g*. Bryan 1997; Lunney *et al*. 1998; Gordon *et al*. 2006; McAlpine *et al*. 2006; Rhodes *et al*. 2006). At a local scale, a finer level of detail is invariably 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, systematic and thus scientifically defendable.

Regularised, Grid-based Spot Assessment Technique (RG-bSAT or GridSAT) sampling has now been applied across several areas in eastern Australia, effectively demonstrating the capacity to provide information about koala population size, distribution and habitat use both at the macro-landscape scale and within localised areas (*e.g*. Phillips *et al*. 2007; Phillips *et al*. 2011; Phillips *et al*. submitted), it is this technique which formed the basis for field sampling throughout the Ballina LGA.

The LGA field survey component was designed to address the following objectives:

(i) obtain a field-based estimate of the contemporary (*i.e*. current koala generation) EoO and associated AoO;

(ii) locate areas currently occupied by resident koala populations;

(iii) obtain an estimate of koala population size; and

(iv) obtain a representative tree-use data set for analysis of koala food tree preferences in order to inform preparation of a koala habitat model.

3.2 Methods

3.2.1 Site Selection

To ensure a uniform and unbiased distribution of survey effort across the study area a 1000m point-based grid overlay was deployed, the resulting points adopted as primary field sites where they intersected areas of vegetation containing Eucalypts. Aerial photography supplied by Ballina Shire Council was utilised to assist this process, sites being excluded where they occurred in water bodies, cleared areas or in vegetation communities that did not

appear to contain eucalypts. Universal Transverse Mercator (UTM) coordinates for the location of field sites were uploaded into a hand-held GPS receiver navigating on a GDA94 datum. In the field, a level of flexibility (5% of sampling scale) was allowed in determining the position of the centre point of the site in order to enable the repositioning of a site into an area determined to be most suitable for sampling (from a koala habitat perspective). Landowners upon whose land potential field sites were located were contacted by Ballina Shire Council seeking permission for a field survey team to enter the land in order for the field assessment to be undertaken.

3.2.2 Habitat Assessment

Once located, each site was sampled using the Spot Assessment Technique (SAT) of Phillips and Callaghan (2011), modified for this project to increase sampling efficiency by applying a default *high use* activity level as soon as ten trees scored positive for koala faecal pellets at any site. Conversely, if the first 25 trees scored negative for faecal pellets, a default *low use* activity level was applied. At each SAT site and irrespective of the faecal pellet search result, a 25m fixed-radius search from the site's centre tree was undertaken for koalas, while if koala faecal pellets were recorded during assessment, larger transect-based searches for koalas (approximating one hectare where practical) was undertaken. Transect searches involved three observers walking approximately 10m apart (depending upon visibility and terrain) and were conducted along a central line generally measuring 125m along the contour in two directions from the centre tree of the field site. The aim of the radial and line transect searches were to enable area-based koala density estimates to be derived.

The results of field survey are reported herein in terms of 'active sites' and 'koala activity'. An active site is defined as any site within which one or more koala faecal pellets were recorded beneath a tree during sampling, while the activity level of a given site is calculated as the percentage of trees within it that scored positive for the presence of koala faecal pellets (Eqn 1).

$$\text{Activity level} = \frac{\text{Number of trees with faecal pellets}}{\text{Number of trees searched}} \times 100 \qquad \text{Eqn 1}$$

A contemporaneous (i.e. current koala generation) occupancy estimate for the LGA area was determined by dividing the number of active field sites by the total number of sites that were assessed. Data used for occupancy calculations was restricted to that derived from

primary field sites only. Sites with recorded koala activity were allocated supplementary field sites at 500m intervals surrounding the active site to increase spatial data fidelity.

3.2.3 Population Modelling

Koala activity data from the field sites was interpolated across the LGA using thin plate splining techniques. Null (zero activity) sites at 500m intervals were incorporated into the modelling process in order to (i) influence the outcome in areas that were devoid of vegetation, and (ii) to effectively delineate distributional and/or dispersal barriers such as the coastline, major rivers and large water bodies.

Output from the splining process was then utilised to produce an activity contour model to effectively delineate areas occupied by resident koala populations (i.e. *Core Koala Habitat* as defined by *SEPP 44*) when interpreted with regard to the activity thresholds of Phillips and Callaghan (2011). This process invariably encapsulates areas occupied by approximately 85% of contemporary koala records and 100% of breeding female koalas (Phillips *et al*. submitted). Both the East Coast (low) and East Coast (med-high) activity category thresholds proposed by Phillips and Callaghan (2011) were applied for the purposes of interpreting koala activity across the LGA (see Table 3.1).

Table 3.1: Categorisation of koala activity based on use of mean activity level ± 99% confidence intervals for each of three area/population density categories. Activity levels in the Medium (normal) and High use range indicates occupancy by resident koala populations (Source: modified from that of Phillips and Callaghan 2011).

Activity Category	Low use	Medium (normal) use	High use
Area (koala density)			
East Coast (low)	-	≥ 9.99% but ≤ 12.59%	> 12.59%
East Coast (med-high)	< 22.52%	≥ 22.52% but ≤ 32.84%	> 32.84%
Western Plains (med-high)	< 35.84%	≥ 35.84% but ≤ 46.72%	> 46.72%

3.2.4 Koala Density Estimates

Unbiased koala density estimates were obtained by dividing the total number of koalas recorded in the 25m (0.196ha) fixed-radius searches associated with each primary field site, by the sum of the total area searched using this method. An additional density estimate, restricted to those areas within which koala activity was known to be present, was derived from the line transect data.

3.3 Results

3.3.1 Habitat Assessment

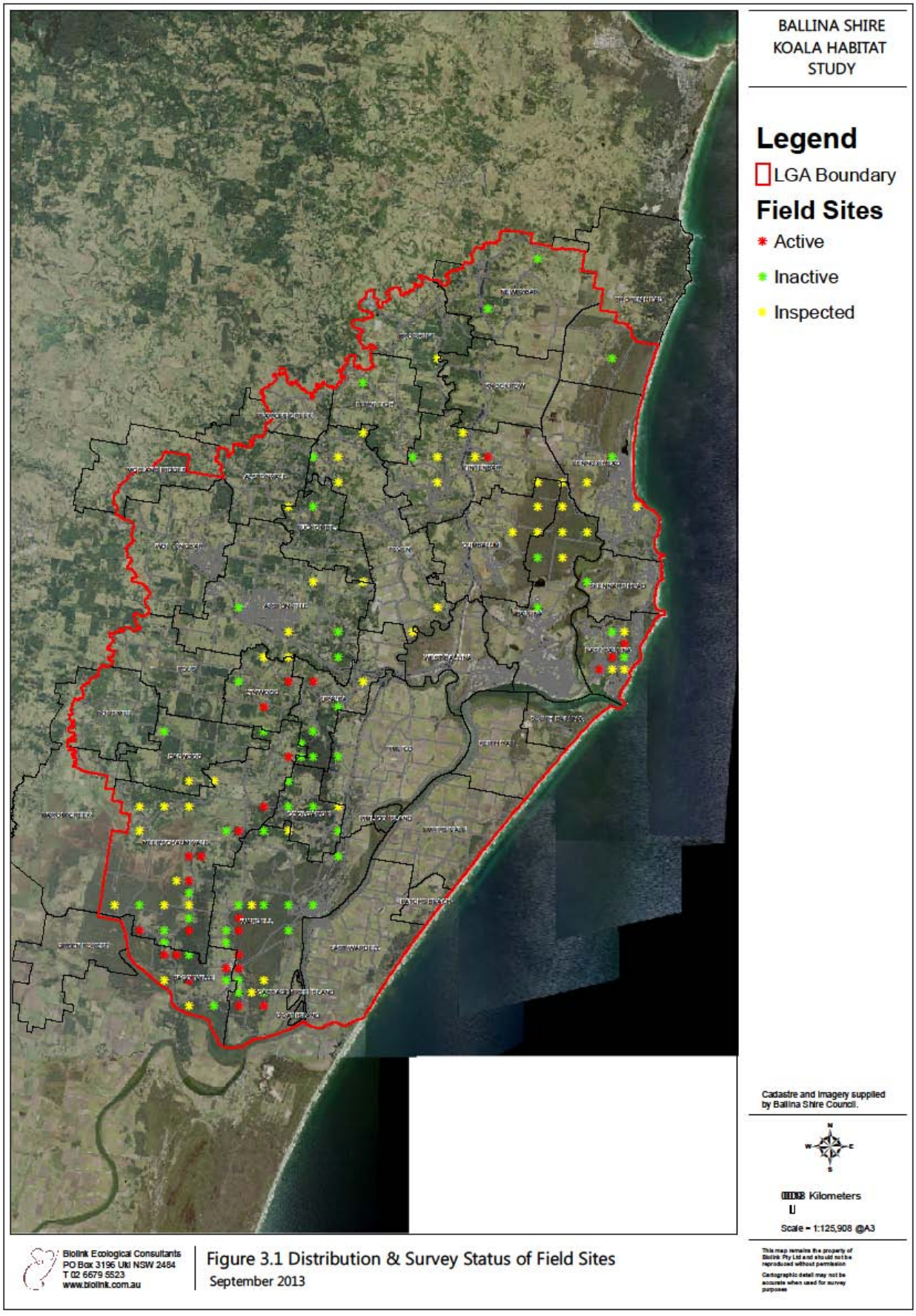
Sampling was undertaken between December 2012 and April 2013 during which time 56 primary and 19 supplementary field sites were assessed. One hundred and twenty three primary field sites were initially identified for sampling, 66 of which were inspected but subsequently not sampled due to either an absence of Eucalypts within a 100m radius of the site coordinates (n = 48) or because they were unable to be assessed as a consequence of landholders not responding to the request for access from Council or formally refusing entry onto their land (n = 18).

Evidence of koala activity (*i.e.* koala faecal pellets recorded beneath at least one tree within the site) was recorded from 25 field sites (Table 3.2) wherein koala activity levels ranged from 3.33% to 69.57% (mean activity level: 12.76 ± 13.66% (SD)). The 18 primary field sites at which koala activity was recorded implied that 31.58 ± 12.07% (95% Confidence Interval (CI)) of available habitat was being utilised by koalas at the time of survey. Notwithstanding the inability of the field survey effort to effectively cover the entire LGA, the greater proportion of recorded koala activity was located in the southern end of the study area.

The distribution of survey effort across the study area is illustrated in Figure 3.1, while the associated site coordinates and resulting activity levels are detailed in Appendix I.

Table 3.2: Summary of primary and supplementary field sites and the intervals at which sites were located.

	Interval (m)	Sites	Active Sites
Primary	1000	56	18
Supplementary	500	20	7
Totals		**76**	**25**


BALLINA SHIRE
KOALA HABITAT
STUDY
Legend
LGA Boundary
Field Sites
Active
Inactive
Inspected
Cadastre and Imagery supplied by Ballina Shire Council.
N
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Scale = 1:125,908 @A3
This map remains the property of Biolink Pty Ltd and should not be reproduced without permission.
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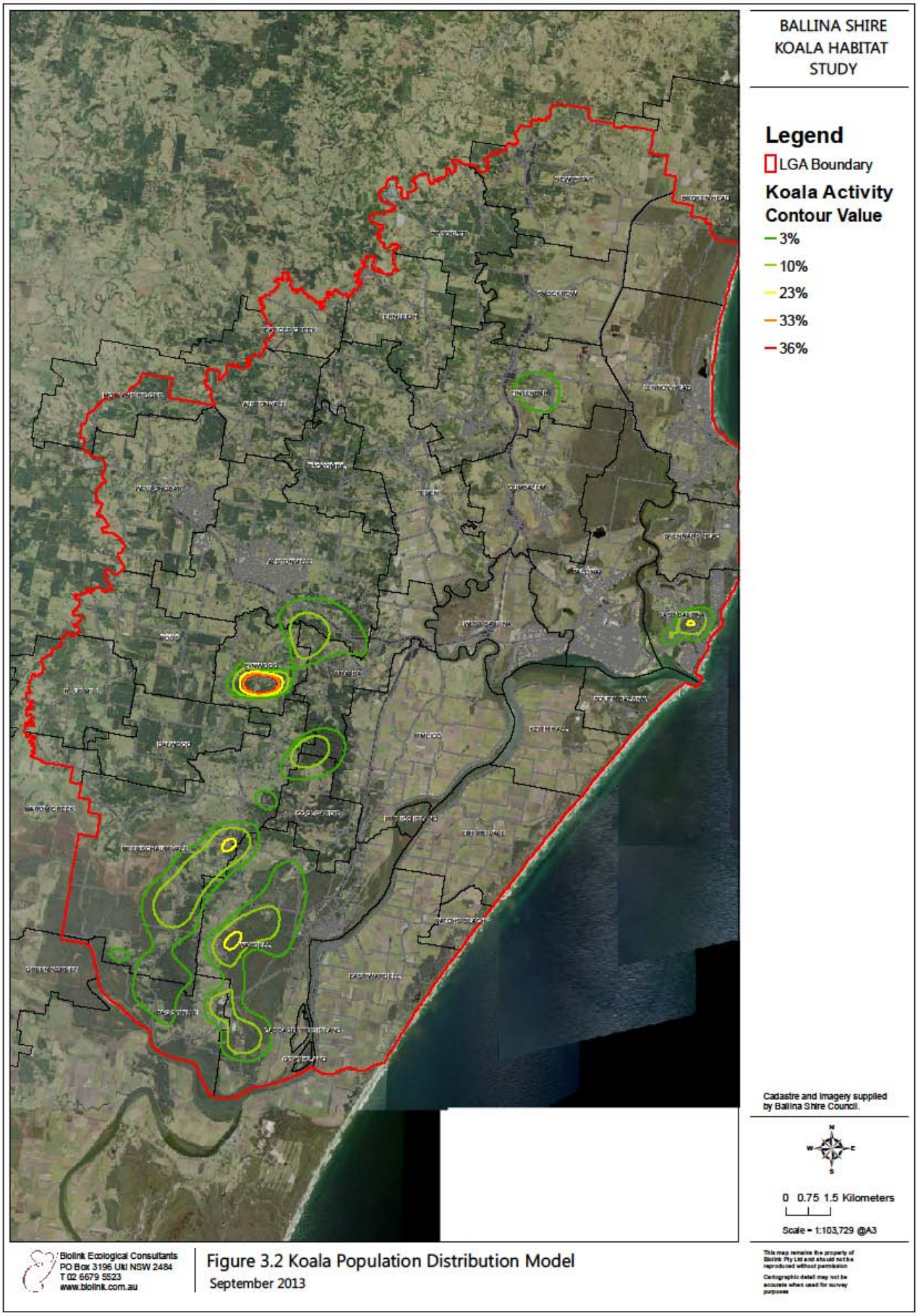
Figure 3.1 Distribution & Survey Status of Field Sites
September 2013

3.3.2 Population Modelling

Within the Ballina LGA koala activity was spatially auto-correlated (clustered) and recorded most frequently south of the Bruxner Highway and west of the Pacific Highway. Qualified by the false absence of koala activity data in the north of the study area due to a combination of fragmentation and private property access issues, a conservative koala population distribution model for the southern part of the LGA area is provided in Figure 3.2. As already alluded to by the historical records analysis, this result confirms the contemporaneous persistence of koala population cells in the Coolgardie, Wardell, Bagotville, Meerschaum Vale, Lynwood and Uralba areas. Smaller population outliers were also apparent in the vicinity of Tintenbar and in East Ballina.

3.3.3 Koala Density & Population Estimates

Seven koalas were observed during the course of the field survey component. Of these records and independently of koala activity, two were recorded within the 10.78ha of habitat sampled by the 25m SAT-based radial koala searches. This data translates to a koala density estimate across the LGA of 0.19 ± 0.10 koalas ha^{-1} (95% CI); an identical density estimate but with greater variance was also obtained on the basis of 3 koalas (includes the 2 aforementioned) being sighted in 16ha of line-transect searches. As discussed in Part 4 that follows, qualified estimates relating to the amount of Preferred Koala Habitat across the LGA range from 1,500 – 2,000ha. On this basis estimates relating to the number of koalas inhabiting the Ballina LGA potentially range from 285 – 380.


BALLINA SHIRE
KOALA HABITAT
STUDY
Legend
LGA Boundary
Koala Activity
Contour Value
3%
10%
23%
33%
36%
Cadastre and imagery supplied
by Ballina Shire Council.
N
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Scale = 1:103,729 @A3
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Figure 3.2 Koala Population Distribution Model
September 2013

3.4 Key Outcomes

- Field survey was undertaken at 76 sites spaced at 1,000m and 500m intervals across the LGA. Distribution of koala activity was widespread but primarily concentrated in the southern half of the LGA, with smaller outliers at East Ballina and Tintenbar. The field-based contemporary occupancy estimate for the LGA approximates 32% of available habitat. This estimate is significantly less than the 60% indicated for the *post*-1994 AoO estimate derived by historical records analysis, but is not significantly different from the 46% estimated by the *pre*-1995 AoO estimate. There are three explanations for this disparity:

  i) while the field based estimate is trending downwards to a greater extent than expected, the difference between *pre*-1995, *post*-1994 and the 2012/13 field-based AoO estimate possibly reflects a population cycling around the optimum value of approximately 50% of available habitat, or

  ii) the field-based AoO estimate reflects a real decline in the occupancy rate independently of that associated with a population cycling around the optimum value, or

  iii) a combination of *i)* and *ii)* above.

  Based on the generally low activity levels that were recorded by the field survey component, it is considered that the most likely explanation for the disparity is *ii)* above, more so when considered in the context of such things as road mortalities (Part 5 refers).

- Population distribution modelling based on koala activity data indicates the ongoing presence of a regionally significant population of koalas in the localities of Coolgardie, Wardell, Bagotville, Meerschaum Vale, Lynwood and Uralba. This population is also likely to be nationally significant as the historical source population for koalas both in adjoining areas of the Lismore LGA and the lower lying areas of the Byron coast to the north, a hypothesis readily testable by genetic analysis.

- A density estimate of approximately 0.19 koalas ha^{-1} has been identified for areas of suitable habitat across the study area. When this figure is extrapolated across an estimate of the amount of Preferred Koala Habitat remaining in the LGA, a population estimate of 285 – 380 koalas results.

Part 4 - Food Tree Preferences & Habitat Mapping

4.1 Introduction

Koala habitat mapping provides an important basis for understanding the distribution and abundance of koalas, in addition to assisting effective conservation planning and priority setting. In order to define the quality and extent of koala habitat it is important to have some understanding as to what elements of the vegetated landscape most influence its use by koalas, invariably these are the species' preferred food trees and associated vegetation. It is widely acknowledged that koalas prefer a relatively small number of the *Eucalyptus* species in a given area (e.g. Hindell and Lee 1987; Ellis *et al*. 1999; Lunney *et al*. 1998; Lunney *et al*. 2000; Phillips *et al*. 2000; Phillips and Callaghan 2000; Ellis *et al*. 2002; Smith 2004; Moore *et al*. 2004). The identification of preferred tree species across large and heterogenous landscapes can be a complex process because there are a variety of factors that influence whether or not koalas are present in the first instance. Considerations include 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). Such uncertainty is recognised in the approved Recovery Plan for Koalas in NSW (DECC 2008) which provides area-based lists of preferred koala food trees, whilst also requiring that food tree use by koalas be thoroughly investigated for a given region.

The ability to produce an ecologically-meaningful map of 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 detail provided by 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 Ballina LGA, with objectives for this component of the study being to:

(i) identify preferred koala food tree species;

(ii) consider and evaluate the potential influence of soil nutrient levels on food tree use; and

(iii) identify and ideally map areas of *preferred koala habitat.*

4.2 Methods

The data set for this part of the study primarily comprised tree use data from the 25 active field sites in which evidence of use by koalas (i.e. the presence of koala faecal pellets) was recorded.

4.2.1 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 (*n*) of a given tree species (*i*) which had one or more koala scats at their base, by the total number of sampled trees (Eqn 2).

$$P = \frac{\text{Number of trees of species } i}{\text{Number of trees of species } i \text{ with scats}} \qquad \text{Eqn 2}$$

Strike-rate data was subsequently partitioned for analysis purposes, the primary data set consisting of tree species for which the number of spatially independent field sites from which it was sampled was ≥ 7 and that n_iP_i and $n_i(1\text{-}P_i)$ were greater than 5. Therefore, the primary data set contains the most commonly sampled tree species as well as those being most frequently utilised by koalas and thus most likely to be of importance in sustaining population(s). Tree species for which n_iP_i and $n_i(1\text{-}P_i)$ were less than 5 but which were otherwise represented in seven or more independent field sites were relegated to a secondary data set for analysis purposes.

Variation amongst strike rates comprising the primary data set was examined using Log-likelihood ratios in the company of an unplanned test for homogeneity by means of simultaneous test procedures, while those in the secondary data set were tested using a Kruskal – Wallis ANOVA, with any significant variation further examined with a Mann-Whitney U/Wilcoxon Rank Sum Test (refer Sokal and Rohlf 1995).

4.2.2 Influence of Soil Landscape on use of PKFTs

Because the palatability of certain tree species by koalas is now known to vary with soil type (Phillips and Callaghan 2000; Phillips 2000b; Moore and Foley 2005) it cannot be assumed that tree preferences, once known, will remain uniform across a given study area. For this reason and primarily informed by the results from other studies, the tree use data set for the LGA was evaluated on the basis of two aggregated soil landscape categories as follows:

(i) Transferral, Alluvial, Swamp, Colluvial and Residual soil landscapes were deemed to be of MEDIUM to HIGH nutrient value; while

(ii) Erosional, Beach and Aeolian soil landscapes were deemed to be of LOW to MEDIUM nutrient value.

4.2.3 Koala Habitat Categorisations

Habitat categorisations were based on the presence/absence of preferred koala food trees rather than "the 15% rule" proposed by SEPP 44. To this end the terms "*Primary*", and "*Secondary*" koala food tree species as used in the following definitions are based on the mathematical models and associated definitions of Phillips (2000b) and are thus consistent with terminology used in the approved Recovery Plan for the Koala (DECC 2008) as 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.

Collectively, the three preceding habitat classifications function to identify areas of ***Preferred Koala Habitat*** across the LGA. Beyond this classification system 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 regarded as **"Unknown".**

It was envisaged that vegetation mapping provided by the Ballina Shire Council would provide the basis for koala habitat classification across the LGA.

4.3 Results

4.3.1 Preferred Koala Food Trees

From a total dataset (all sites) of 2,073 trees, a sub-set of 765 trees from 25 active sites provided information on the use of different tree species by koalas. From these data, 417 trees comprising 5 species of *Eucalyptus* and 4 non-eucalypt species met the criteria for inclusion in the primary and secondary data sets, wherein strike rates ranged from 30% for Tallowwood (*Eucalyptus microcorys*) to 4% for Brush Box (*Lophostemon confertus*) and

Forest Oak (*Allocasuarina torulosa*). Table 4.1 details the overall result arranged in terms eucalypt and non-eucalypt data sets respectively.

The primary data set contained only two species (which were also the most preferred), Tallowwood (*E. microcorys*) and Swamp Mahogany (*E. robusta*), which did not differ significantly in their strike rates (G = 0.161; 1_{df}; P>0.05). The secondary data set contained 3-4 species of *Eucalyptus* and 4 species of non-eucalypt within which variation was not determined to be significant (H = 2.6136; 6_{df}; P>0.05).

4.3.2 Inactive Sites

A sub-set of 1,308 trees from 51 inactive sites were associated with an absence of koala activity. Data from these sites is presented in Table 4.2 for two reasons: firstly because it serves to represent the results of extensive field survey effort across the study area and secondly because it is invaluable in terms of confirming that the widespread absence of koala activity from such sites is not simply a reflection of a lack of preferred koala food tree species.

4.3.3 Use of Preferred Food Tree Species

Informed by studies in the Byron and Tweed LGAs (Hopkins and Phillips 2012; Phillips *et al.* 2011), Forest Red Gum (*E. tereticornis*) and the naturally occurring *E. robusta* x E. *tereticornis* hybrid, were added to the list of preferred koala food tree species for the LGA. These additions facilitated development of the following decision path to enable habitat classification:

- Forest Red Gum[1], Tallowwood and Swamp Mahogany function as Primary koala food tree species when growing on medium or high nutrient soil landscapes;
- Tallowwood functions as a Secondary[2] koala food tree species when growing on low to medium nutrient soil landscapes.

[1] Includes the naturally occurring *E. tereticornis* x *E. robusta* hybrid.
[2] Other species including Grey Gums and 'Boxes' may occur as windrow plantings.

Table 4.1. Tree species comprising the tree use data set for the LGA (*n* = number of independent field sites; *P* = strike rate; *SE* = Standard Error).

		Sites	*n*	*P* ± SE
Primary Data Set				
Eucalypts				
E. microcorys	Tallowwood	13	77	0.30 ± 0.05
E. robusta	Swamp Mahogany	9	88	0.22 ± 0.04
Secondary Data Set				
Eucalypts				
E. acmeniodes/carnea	White Mahoganies	8	48	0.06 ± 0.02
E. pilularis	Blackbutt	8	32	0.09 ± 0.05
E. resinifera	Red Mahogany	7	28	0.11 ± 0.07
Non-eucalypts				
Acacia melanoxylon	Blackwood	7	13	0.08 ± 0.07
Allocasuarina torulosa	Forest Oak	8	28	0.04 ± 0.04
Corymbia intermedia	Pink Bloodwood	10	46	0.07 ± 0.04
Lophostemon confertus	Brush Box	9	57	0.04 ± 0.02
Other Data				
Eucalypts				
E. dunnii	White Gum	1	1	-
E. fibrosa	Red Ironbark	1	5	-
E. globoidea	White Stringybark	1	3	-
E. grandis	Flooded Gum	1	1	1.00 ± 1.00
E. racemosa	Scribbly Gum	2	12	-
E. saligna	Sydney Blue Gum	5	30	0.13 ± 0.06
E. siderophloia	Grey Ironbark	4	11	-
E. tereticornis	Forest Red Gum	1	7	0.29 ± 0.17
E. sp	unidentified	1	4	0.50 ± 0.25
Non-eucalypts				
Banksia spp.	Banksia	3	13	0.08 ± 0.07
Callistemon salignus	Willow Bottlebrush	2	2	-
Callitris columnellaris	Cypress Pine	2	4	0.25 ± 0.22
Casuarina glauca	Swamp Oak	2	4	-
Cinnamomum camphora	Camphor Laurel	6	53	0.13 ± 0.05
Corymbia citriodora	Spotted Gum	1	2	-
C. gummifera	Red Bloodwood	3	7	-
C. torrelliana	Cadaghi	1	3	-
Endiandra sieberi	Hard Corkwood	2	3	0.33 ± 0.27
Lophostomen suaveolens	Swamp Turpentine	2	6	-
Melaleuca quinquenervia	Broad-leaved Paperbark	6	65	0.12 ± 0.04
Syncarpia glomulifera	Turpentine	3	11	0.09 ± 0.09
-	Misc spp.	-	101	-

Table 4.2. Summary of tree species data from non-active sites. The number of trees (*n*) and number of associated SAT sites within which each species was sampled is also provided. * = known koala food tree species, including those identified as preferred by this study.

		Sites	*n*
Eucalypts			
E. acmenoides/carnea	White Mahogany	10	35
E. dunnii	White Gum	3	33
E. fibrosa	Red Ironbark	1	5
E. grandis	Flooded Gum	5	21
*E. microcorys**	Tallowwood	11	69
E. pilularis	Blackbutt	15	73
*E. propinqua**	Grey Gum	1	11
E. racemosa	Scribbly Gum	3	26
E. resinifera	Red Mahogany	6	11
*E. robusta**	Swamp Mahogany	15	105
E. saligna	Sydney Blue Gum	5	24
E. seeana	Narrow-leaved Red Gum	1	6
E. siderophloia	Grey Ironbark	2	5
*E. tereticornis**	Forest Red Gum	1	1
E. sp.		2	2
Non-eucalypts	Various spp.		881
Total Trees			**1,308**

4.3.4 Koala Habitat Categorisations

Available vegetation mapping for the Ballina LGA comprised exceptionally detailed, high resolution line work delineating 13,876 polygons that collectively capture some 15,111ha of vegetation cover. Unfortunately, only 64% (approximately) of the captured polygons have thus far been identified to vegetation community level, a circumstance no doubt exacerbated by the extent of fragmentation across the LGA which results in approximately 80% of mapped polygons being less than 1ha in size. Additionally, for those polygons that had been allocated a name as at the time of preparing this report, the lack of application of a standardised typology has resulted in approximately 280 vegetation community types being designated. In contrast, recent Class 5 vegetation mapping across the Coffs Harbour and Port Macquarie LGAs recognised a maximum of 79 and 83 vegetation communities respectively (Office of Environment & Heritage 2012; Biolink 2013).

Despite our efforts, the lack of specific detail relating to the presence/absence and densities of preferred koala food tree species in each of the captured polygons did not enable an objective koala habitat classification exercise to be applied such that we could have prescribed a measure of confidence beyond approximately 50%. In order to assist resolution of this issue we further determined to consider vegetation cover across the LGA from other

perspectives: firstly on the basis of a “without prejudice” acceptance of the vegetation data assisted by discussions and advice from Council officers, secondly by way of an independent compartmentalised assessment as to the extent (proportion) of forest cover containing *Eucalyptus* spp. within each of the 75 x 625ha grid-cells previously utilised to assist interpretation of the historical records. In both instances we also relied upon data from field sites that had been assessed as part of this project, including notes and observations of field officers.

Unfortunately, the preceding approaches yielded disparate results; the combined approach of existing mapping plus consultation with Council officers implying that approximately 4,041ha of vegetation cover across the LGA contained one or more of the preferred koala food tree species and so qualified as preferred koala habitat (Table 4.3). However, this outcome was strongly influenced by extensive tracts of Broad-leaved Paperbark (*Melaleuca quinquenervia*) dominated forests wherein field data and observations indicated that the greater proportion of this community did not contain food trees; this consideration was considered to overestimate the extent of preferred koala habitat by as much as 50%.

Table 4.3. Mapped area (in hectares) for each category of koala habitat identified within the LGA based on Council’s existing vegetation mapping layer, SAT field sites and consultation with Council officers. Note the extensive areas of “Other” habitat arising from unlabelled polygons within the mapping layer. This outcome potentially overestimates the extent of Preferred Koala Habitat within the LGA by as much as 50%.

	Habitat Category	Area (ha)
Preferred Koala Habitat	Primary	87
	Secondary A	2,215
	Secondary B	1,739
Other Habitat	Other	10,099
	Unknown	971
Total		**15,111**

In contrast to the above, the compartmentalised assessment estimated the extent of vegetation cover containing *Eucalyptus spp*. (*i.e.* without regard for presence/absence of preferred food tree species) to be no more than approximately 1,500ha. Interestingly, this result was also considered to overestimate the extent of koala habitat given knowledge from field survey that not all areas of Eucalypt forest contained preferred koala food tree species. This realisation was mitigated by knowledge that not all areas containing *Eucalyptus spp*. were detectable, most notably windbreaks on farming land on the Alstonville Plateau comprised in most instances of a single row of Eucalypts which were not readily distinguished from other tree species in the general area. The extent to which this circumstance influences the presence/absence of koalas, extent of habitat utilisation and

associated habitat modelling is perhaps best expressed in the notes made by Team Leader Dan Pollard in relation to Site No 1K57 during the course of the field survey as follows:

"*Only C. camphora at field site with occasional rainforest species. No koala activity detected. Windrow of E. microcorys ~ 240m away on a bearing of 40^{o}; very obvious pellets – would be high use site. Quick inspection at base of trees yielded 10/10…pellets were of varying size."*

From our perspective the disparate nature of the preceding outcomes and the need to (be able to) finely partition the vegetation mapping layer indicated that caution was warranted during the processes of koala habitat classification modelling. Consequently it was considered that any resulting koala habitat map would be a less than objective outcome and so would be not be a dependable source to inform any subsequent koala-specific planning measures and/or actions. For this reason we constructed a decision-tree flowchart (Appendix 2) to guide the classification process by enabling land owners, Council officers and other stakeholders to independently determine the koala habitat status of vegetation polygons/communities on their land. We would envisage that this decision tree be used as part of any refinement of what is otherwise a highly refined vegetation mapping layer.

4.4 Key Outcomes

- Trends in the tree use data set, coupled with knowledge from studies in adjoining LGAs indicate that a suite of three *Eucalyptus* species comprising Tallowwood, Forest Red Gum[1] and Swamp Mahogany are the most preferred tree species for koalas in the study area. Forest Red Gum, Tallowwood and Swamp Mahogany function as primary food tree species when growing on med-high nutrient soil landscapes, whereas Tallowwood likely functions as a secondary food tree species on lower nutrient soils.
- Available vegetation mapping is not sufficiently informed to enable an objectively derived map of koala habitat to be created. A total of between 1500ha and 2000ha of *Preferred/Potential Koala Habitat* is considered likely based on information associated with mapped polygons and field survey data, with all three habitat categories recognised by the Koala Recovery Plan being represented.

Part 5 - Threatening Processes

5.1 Habitat Loss & Fragmentation

Loss of koala habitat (occupied or otherwise) continues to contribute to population decline across the koala's range, while the influence of patch size, patch shape and levels of connectivity also appear to be key factors determining the ability of a given landscape to support viable populations. Subject to some qualifications, work by McAlpine *et al.* (2007) indicates that the probability of koalas being present can fall as the percentage of the landscape containing forest cover 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.

The survival of koala meta-populations (a group of sub-populations connected by dispersal and recruitment processes) relies on the ability of individuals 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 habitat matrix and the existence of barriers to movement. Koala habitat within the Ballina LGA is perhaps the most extensively fragmented of any we have thus far assessed, with the largest contiguous areas of remaining habitat associated with the Blackwall Range area from Uralba through Coolgardie and down to Wardell Bagotville & Meerschaum Vale. Hence the maintenance of habitat patches of sufficient size to support existing populations and provide for future population expansion will be fundamental to long-term koala population and habitat management within the LGA generally.

5.2 Dog Attack

Attacks by domestic dogs are a significant contributor to koala mortality (QGEPA 2006; DECC 2008). The impact of domestic dog attack on koala populations increases with urbanisation and habitat fragmentation. A higher frequency of cleared areas means individual koalas are required to travel greater distances in order to access resources, increasing the amount of time spent on the ground and thus their vulnerability to attack. Data from the FoK database indicate at least 5% of koala call-outs in the Ballina LGA were associated with domestic dog attacks. It is expected that the reporting rates for dog attacks on koalas are lower in more rural-residential areas and therefore the actual percentage will

invariably be higher. Presumably as a result of domestic dog attacks, localised extinctions of koalas in bushland areas once known to be supporting resident populations but since transformed into rural-residential developments can be demonstrated in at least three areas in Port Macquarie (Phillips unpub. data). Elsewhere, attacks by domestic dogs constitute approximately 15% of all admissions to the Port Macquarie Koala Hospital (Cheyne Flanagan, pers comm.) while data from southeast Queensland indicates high measures of domestic dog related mortalities each year, the threat being ranked as the third most important in this region (DERM 2009) and fourth in NSW (DECC 2008).

Attack by domestic dogs should be considered a significant contributor to the suite of threats to koalas in the rural-residential areas of the Ballina LGA.

5.3 Road Strike

Incidences of recorded koala mortalities associated with road kills in the historical records database over the time period 1949-2012 are scarce. However, qualitative spatial analysis of the FoK and NSW Atlas records indicate an incidence of unrecorded or unexplained but linearly aligned koala mortalities along the Wardell Road between Meerschaum Vale and Wardell, the Bruxner Highway between Wollongbar and its intersection with the Pacific Highway towards the base of the Alstonville Plateau and lastly the Pacific Highway between the Coolgardie Road intersection and Wardell. Such data does not reflect the full extent of koala road-kill because many mortality records do not have relevant information associated with them, nor are all koala road-kills reported.

A further koala “black spot” within the LGA will potentially be created in association with construction of the Wardell by-pass arising from the Woolgoolga to Ballina Pacific Highway upgrade. Significantly, the by-pass is proposed to traverse an area identified by this study as supporting koalas over at least the last 6 consecutive koala generations.

5.4 Fire

Stochastic and poorly-planned fire events continue to threaten koala populations throughout most areas of eastern Australia and are increasingly being recognised as a key factor influencing long-term viability of koala populations (Phillips and Pereoglou 2005, Phillips *et al*. 2011). Wildfire has the potential to exacerbate koala population decline (Starr 1990; Melzer *et al*. 2000) as each high-intensity or high-frequency fire event 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 while widespread canopy scorch can impose nutritional stress leading to starvation for remaining animals (Melzer *et al*. 2000).

5.5 Disease

Disease is a fundamental aspect of wildlife population dynamics and a phenomenon generally recognised as a density-dependent mechanism affecting population regulation. This is also the case with koalas where reproductive output/population size can be reduced by elevated levels of disease 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. Unfortunately, at the urban-bushland interface such stressors become compounded by the addition of more anthropogenic catalysts such as habitat loss, dog attack and motor vehicle strike, the consequences of which tend to manifest as elevated levels of clinical expression of disease, reduced reproductive output and mortality.

Disease features prominently in the historical records, both in terms of the underlying basis for many of the records but also as a contributing factor to koala mortality across the LGA. It is thus of interest that disease *per se* does not appear to have significantly influenced the overall trend of population expansion over at least the last 6 koala generations. *Chlamydia* and Koala retro-virus (KorV) are known to be present in the Ballina koalas, the extent to which they collectively contribute to overall mortality rates being arguably more symptomatic of disturbance than anything else. Thus disease alone is not considered by this report to be a direct or overriding threat to long-term koala population viability in the LGA providing that sufficient areas of habitat remain in the south so as to effectively buffer this nationally significant source population from undue disturbance.

5.6 Koala Care & Welfare

There is an ongoing requirement for an effective mechanism for managing koala casualties resulting from vehicle strike and domestic dog attack, wildfire and other stressors. In NSW wildlife welfare and carer groups are licensed to rescue, rehabilitate and release native fauna under Sections 120, 132C and 127 of the *National Parks and Wildlife Act 1974*. Based in the adjoining Lismore LGA, *Friends of the Koala* (FoK) is a non-profit community group run by volunteers who operate a rescue service for sick, injured and orphaned koalas. Consultation with the FoK has identified a number of issues that could be addressed and/or investigated in order to assist its ongoing operation and so improve care for koalas in the

region. The need for ongoing recruitment of active carers, sourcing of financial and in-kind assistance for ongoing equipment and training, along with the establishment of a food tree plantation have been identified as priorities for koala care.

Part 6 - Conclusion & Recommendations

6.1 Overview & Prognosis

The preceding sections of this report serve to provide the first comprehensive overview and assessment of the distribution, abundance and habitat needs of koalas in the Ballina LGA. In this context the project has benefited from the application of a number of assessment techniques not previously available, hence a framework for moving towards a more informed management of koalas across the LGA now exists.

This study has produced unexpected results from almost all its constituent parts, commencing with the analysis of historical koala records which established that, in common with the adjoining Lismore and Byron LGAs, the *Extent of Occurrence* of koalas across the LGA has expanded by approximately 24% over the last 3 koala generations. This outcome is encouraging when considered in the context of broader State-wide trends of decline in Queensland and NSW that otherwise resulted in the listing of the koala as a Vulnerable species in these States and the ACT by the Commonwealth Government in 2012. *Area of Occupancy* data is generally considered the more important of the two range parameters because it implies how much habitat is actually being utilised within the *Extent of Occurrence*. In this context, and in keeping with the trend towards range expansion, results arising from analysis of records again indicated a statistically significant increase over the last 3 koala generations in terms of the amount of habitat occupied by koalas.

Generational Persistence Assessment has also been informative, establishing the long-term (i.e. greater than 6 consecutive koala generations) persistence of what is clearly a significant source population extending southwards along the Blackwall Range from Uralba/Lynwood through Coolgardie and into more lowland habitats around Bagotville, Meerschaum Vale and Wardell. The persistence and extent of area occupied by this population during the middle decades of the 20th century, when koala populations elsewhere in the adjoining Lismore and Byron LGAs were yet to become established, strongly suggests that this may be a regionally significant source population from which these others may well have originated. The challenge ahead for sustainable koala management is ensuring that the processes that have enabled this population to survive thus far are able to be maintained in a landscape of escalating threats from ongoing subdivision of land, fire, private native forestry and the upgrading of the Pacific Highway.

Field survey results conflict with the conclusions of the historical record analysis regarding the amount of habitat currently occupied by koalas across the LGA, with only 32% of primary field sites returning evidence of occupancy and/or habitat use. Outwardly, the fact that there

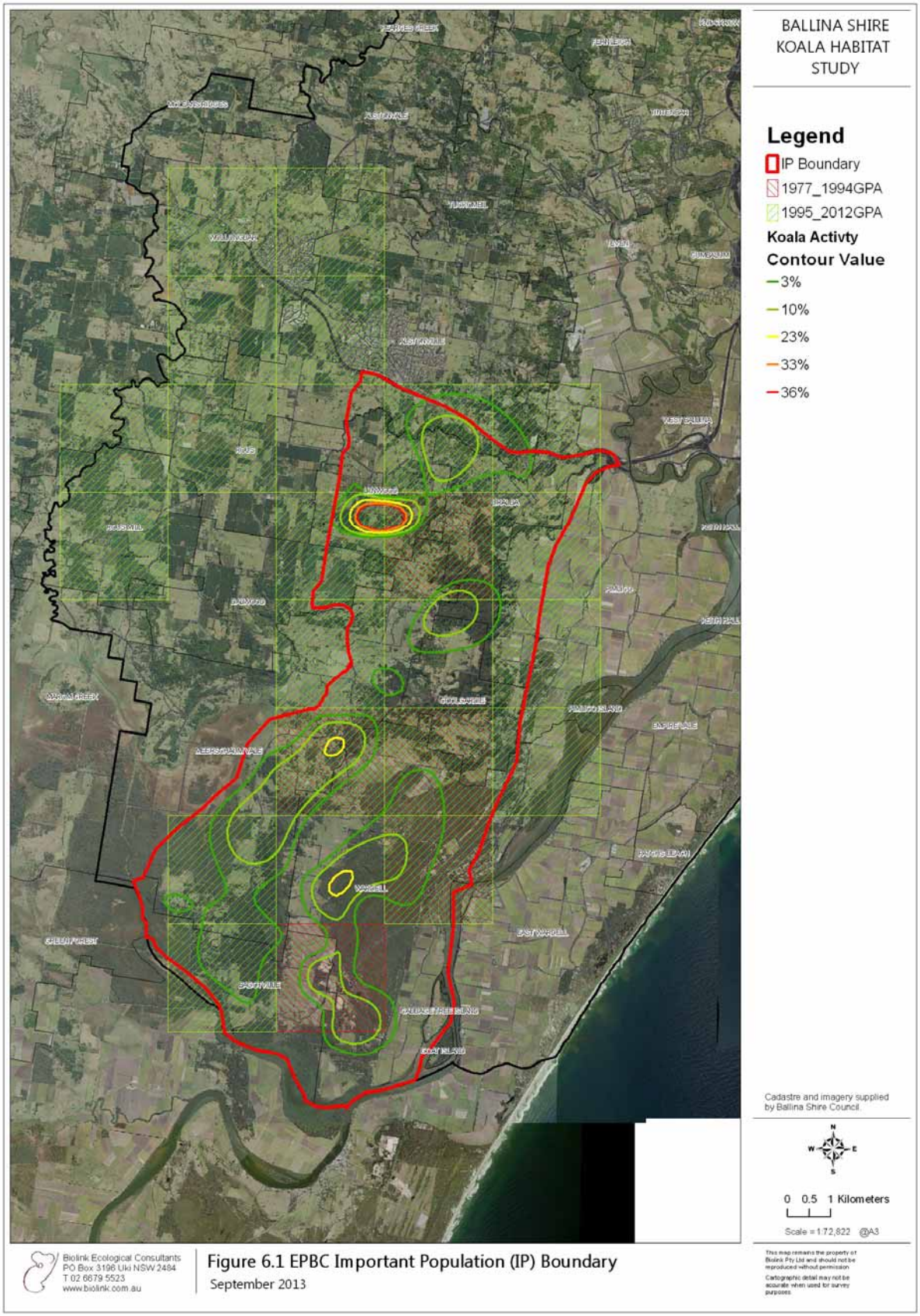
is a substantial difference between the occupancy rate estimated by historical records analysis and that provided by field survey suggests that the population as a whole has experienced some disruption in more recent koala generations. The trend towards decline is supported by field survey outcomes in the south of the study area where activity levels were both lower and more disjunct than what would otherwise be expected on the basis of historical records analysis. The reasons for this remain unclear but are possibly a consequence of fragmentation and a largely unsustainable road mortality that has been occurring over many years. In this context, the fact that over 70% of active primary field sites were located around the Wardell – Meerschaum Vale – Coolgardie area also implies that a similar proportion of the total koala population is also located in this area. This exposes the LGA's population as a whole to a disproportionate risk or vulnerability to threats.

Field data alludes to a koala population estimate for the LGA of 285 – 380 koalas, this number being less than what was generally expected on the basis of historical records and (outwardly at least) the extent of eucalypt forest potentially available to koalas. Within the Eucalypt forests that remain across the Ballina LGA, Swamp Mahogany, Forest Red Gum and Tallowwood have been identified as the tree species most preferred by koalas. This knowledge has implications for koala management on freehold lands where private native forestry operations can also be expected to target tree species such as Tallowwood, especially in the upland areas of Secondary (Class B) koala habitat on lower nutrient soils, wherein current knowledge indicates that smaller size-class Tallowwood (i.e. those below about 350mm dbh) will not be preferentially utilised by koalas.

The basis for a koala management template for the Ballina LGA can be established by overlaying Generational Persistence output with that arising from the field survey component and so identifying key koala management localities. Figure 6.1 presents this overlay so as to provide a context for Recommendation 2 below, confirming the value and utility of the assessment techniques used by this study to inform conservation and management outcomes. The challenge ahead will be how best to integrate this knowledge into meaningful outcomes for this particular population and so generate an overall koala management strategy for the LGA.

It remains difficult to conclude this report with a confident prognosis regarding the future of koalas within the Ballina LGA. The disparity between the historical records analysis and field survey data suggests that recovery focused management actions are already required in more southern parts of the LGA, the objective being to increase the occupancy rate and therefore the resilience of resident populations in these areas. There is also a need to focus

conservation and management effort into this area both prior to and during the construction of the Wardell by-pass. Efforts towards the overall objectives for koala conservation and management in this key area should ensure a focus on the long-term survival and sustainable management of what is considered to be a koala population of local, regional and national significance.


BALLINA SHIRE
KOALA HABITAT
STUDY
Legend
IP Boundary
1977_1994GPA
1995_2012GPA
Koala Activty
Contour Value
3%
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Cadastre and imagery supplied by Ballina Shire Council.
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Figure 6.1 EPBC Important Population (IP) Boundary
September 2013

6.2 Recommendations

The following recommendations are provided to stimulate further discussion and provide focus for some of the key issues to be considered by Council as it ideally moves towards integration of the outcomes of this study into an informed planning response.

Recommendation 1: Until such a time as a Comprehensive Koala Plan of Management or other appropriate planning instrument becomes available, all areas of Preferred Koala Habitat encapsulated by the 10% activity contour and/or located within any 625ha grid cell independently identified as an area of contemporaneous Generational Persistence (i.e. persistent records across each of last 3 koala generations), as illustrated in Figures 2.3, 3.2 and 6.1 of this report, should be regarded as *Core Koala Habitat* for purposes of *SEPP 44* and the *Native Vegetation Act 2003.*

Recommendation 2: The listing of the koala as a Vulnerable species for purposes of the *Environmental Protection and Biodiversity Conservation* (EPBC) *Act 1999* requires proponents to consider referral where a proposed activity has the potential to negatively impact an 'important' koala population. To this end it is recommended that all areas of Preferred Koala Habitat within the red polygon outlined in Fig 6.1 be considered as supporting an <u>important</u> population for purposes of the EPBC Act Significant Impact Guidelines, the general boundaries of which are as follows:

"*That area bounded by the current alignment of the Pacific Highway south from the bridge over Duck Creek to the west of Ballina and southwards to the Richmond River at Wardell, thereafter along the Richmond River to the junction of Marom and Yellow Creeks extending upstream along Yellow Creek to Wardell Road and along Wardell Road to Alstonville, and thereafter east along the Bruxner Highway to its intersection with the Pacific Highway, again in the vicinity of Duck Creek*."

The two EPBC Act criterion satisfied by this population are as follows:
a) as demonstrated by both the historical records analysis <u>and</u> field survey results, it is a key source population for breeding and/or dispersal and
b) when considered in the context of genetic knowledge regarding koala populations in adjoining Lismore LGA to the west and the coastal lowlands of the Byron LGA to the north, it is also likely to be an ancestral source population that is necessary for maintaining genetic diversity.

Recommendation 3: Further progression towards a Comprehensive Koala Plan of Management for the Ballina LGA would be assisted by provision of a map detailing areas of Preferred Koala Habitat. In order for this to occur, further refinement of the current vegetation mapping layer so as to provide more detailed information on the presence/absence of preferred koala food tree species should be regarded as a high priority project.

Recommendation 4: In collaboration with NSW Roads & Maritime Services, Council should pursue the need for a rigorous evaluation of ameliorative options for koalas along future upgrades to the West Ballina – Broadwater section of the Pacific Highway, specifically at the proposed Wardell bypass section. The intent of this evaluation should be to ensure that the movement needs of koalas during the construction phase can be accommodated, whilst after completion all opportunities for both safe passage under the highway and exclusion of access to the road corridor by koalas have been maximised.

Recommendation 5: There is a need for Council to consider development and installation of measures that will work to effectively minimise road-strike at known koala blackspots. This includes locations that are the responsibility of Council to maintain and those within the area identified by Recommendation 2 above.

Recommendation 6: There is a need for Council to develop and adopt a set of stringent Development Control measures that will work to ensure that all future developments within key koala population or habitat areas will consistently result in implementation of 'best-practice' koala-friendly planning measures.

Recommendation 7: Windrows and barrier plantings containing koala food trees have become an important habitat for the Ballina LGA's resident koala populations. Council could consider the need to facilitate meetings between landholders and other stakeholders with a view to establish a long-term management strategy for these areas that is amenable to both landowners and koalas.

Recommendation 8: There is a need for Council to develop "minimum data set" assessment standards to ensure that a high standard of assessment by ecological consultants is maintained into the future. It is this level of assessment that must inform development and future planning decisions across the LGA.

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Appendices

Appendix I

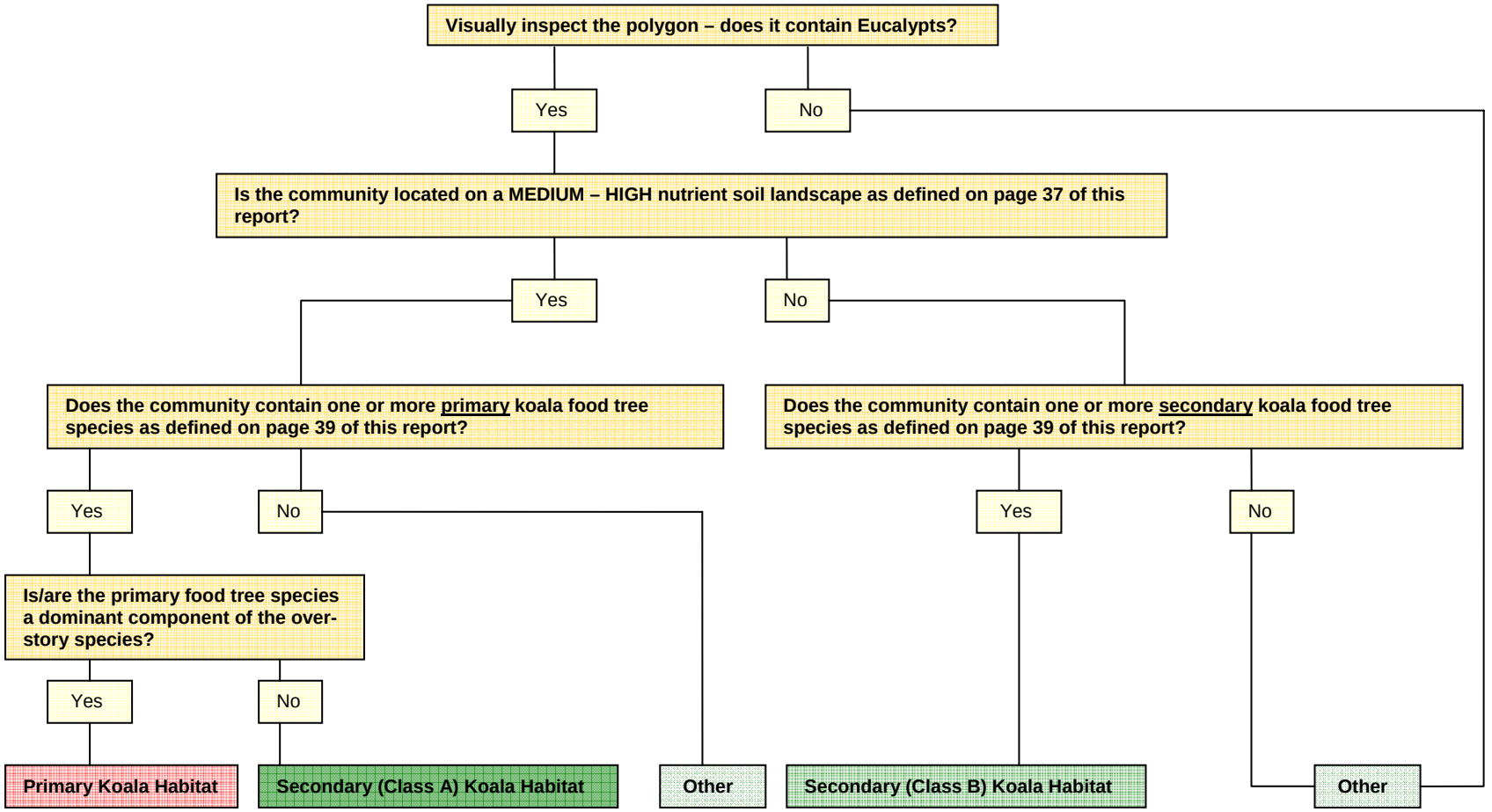
Location and activity levels of Primary field sites across LGA

Site No.	Easting	Northing	Activity
IK 002	541245	6793508	0.00
IK 003	542239	6793470	13.33
IK 004	543250	6793533	6.90
IK 006	540226	6794518	3.70
IK 007	542235	6794525	0.00
IK 009	539264	6795540	7.41
IK 010	540291	6795496	0.00
IK 011	542238	6795512	10.00
IK 013	538278	6796470	3.33
IK 014	539218	6796498	0.00
IK 015	540256	6796521	3.33
IK 016	542252	6796511	16.67
IK 017	544253	6796505	0.00
IK 020	538237	6797477	0.00
IK 023	542243	6797547	0.00
IK 024	543313	6797601	0.00
IK 025	544238	6797485	0.00
IK 026	545256	6797474	0.00
IK 027	540288	6798529	20.00
IK 030	540320	6799636	3.33
IK 031	546224	6799514	0.00
IK 033	542211	6800517	20.00
IK 034	543245	6800537	0.00
IK 036	546271	6800495	0.00
IK 041	543255	6801535	3.33
IK 042	544271	6801480	0.00
1K 043	545197	6801505	0.00
IK 049	544245	6802463	0.00
IK 053	544255	6803547	3.33
IK 054	545241	6803489	0.00
IK 055	546213	6803523	0.00
IK 059	539209	6804523	0.00
IK 061	543205	6804550	0.00
IK 062	545260	6804504	0.00
IK 066	543257	6805558	69.57
IK 068	546246	6805495	0.00
IK 072	542283	6806482	0.00
IK 073	544215	6806498	6.67
IK 074	545279	6806549	6.67
IK 079	546244	6807510	0.00
IK 080	557178	6807519	23.33
IK 083	546255	6808484	0.00
IK 086	557251	6808504	0.00
IK 087	542239	6809567	0.00
IK 090	554277	6809503	0.00
IK 094	556236	6810466	0.00
IK 105	545225	6813555	0.00
IK 118	545280	6815533	0.00

IK 120	549278	6815541	0.00
IK 122	552235	6815520	8.00
IK 123	557182	6815337	0.00
IK 126	547258	6818545	0.00
IK 128	557196	4819558	0.00
IK 131	552255	6821524	0.00
IK 133	554207	6823507	0.00
Supp LH2	557845	6819778	0.00
Supp LH3	557357	6820041	0.00

Appendix 2

Koala Habitat Classification Decision Tree


Visually inspect the polygon – does it contain Eucalypts?
Yes
No
Is the community located on a MEDIUM – HIGH nutrient soil landscape as defined on page 37 of this report?
Yes
No
Does the community contain one or more primary koala food tree species as defined on page 39 of this report?
Does the community contain one or more secondary koala food tree species as defined on page 39 of this report?
Yes
No
Yes
No
Is/are the primary food tree species a dominant component of the over-story species?
Yes
No
Primary Koala Habitat
Secondary (Class A) Koala Habitat
Other
Secondary (Class B) Koala Habitat
Other