NAMBUCCA VALLEY
NAMBUCCA SHIRE COUNCIL

Koala Habitat Study for the Nambucca Shire Council Coastal Area

DECEMBER 2015

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Executive Summary

The study aimed to examine the historical and recent distribution of koalas, in the eastern, coastal zone of the Nambucca Shire Council Local Government Area (Nambucca LGA), through an analysis of all available koala records across all land tenures (primarily from the Atlas of NSW Wildlife) and field surveys across private land within the coastal koala habitat study area. Some 498 koala records from the Nambucca LGA were used to analyse trends in distribution and persistence over time. Field surveys were undertaken at 126 sites across the koala habitat study area, with koala activity recorded at 15. Opportunistic searches identified an additional four active sites. An assessment of key threats to koalas in the study area was also undertaken. The results, outcomes and recommendations of this study are intended to inform Nambucca Shire Council's regional and strategic planning and may contribute to the preparation of a Comprehensive Koala Plan of Management for the coastal study area of the Nambucca LGA.

The Nambucca LGA is located on the Mid North Coast of New South Wales, midway between Sydney and Brisbane. The LGA covers an area of approximately 149 100 hectares, extending from the coast inland to the escarpment of the Great Eastern Ranges. The historical homeland of the Gumbaynggirr Aboriginal people extends to the north of the Nambucca River in the LGA and the homelands of the Dunghutti people lie to the south of the river. It is thought that local tribes used koalas, together with other species, for food and for their skins. Europeans first explored the area in 1820, and the cutting of red cedar (*Toona ciliata*) is believed to have begun in about the 1840s. From this time there was significant land clearing and ringbarking for the establishment of agriculture as well as habitat disturbance from forestry, the introduction of weeds and changing fire regimes. Today, large areas of the floodplains, valleys and mid-slopes of the LGA have been cleared, significantly reducing the availability and quality of habitat available for koalas. This reduction and fragmentation of koala habitat likely peaked in the period from the late 1890s to the mid 1900s, when koala abundance and distribution were probably at their lowest.

This study has found that koalas persist in many forested areas in the study area and, in particular, in the northern areas to the north and north-west of Nambucca Heads. In this area, there is recorded evidence of persistence of koalas over 3–4 koala generations, equivalent to a period of 18–24 years. This finding is supported in both the analysis of koala records and the results of the field surveys.

Both the records analysis and the field surveys, however, also showed a trend of decline in some parts of the study area, particularly in the area south and east of the township of Macksville, to the west of Scotts Head and to the north of Warrell Creek.

Although there were too few records to calculate occupancy rates for areas supporting koalas, occupancy rates are likely to be below optimal level (50%) but are likely to be similar to areas observed in other north coast studies (e.g. 28% in the Byron Coast Koala Habitat Study). Active management will be required to ensure the long-term persistence of koalas within the coastal areas of the Nambucca LGA.

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1 Introduction

This study set out to examine the historical and recent distribution of koalas in the coastal part of the Nambucca Shire Council Local Government Area (Nambucca LGA), through an analysis of historical records and field surveys undertaken as part of this study. An assessment of key threats to koalas in this area was also undertaken. The results, outcomes and recommendations of this study are intended to inform Nambucca Shire Council's regional and strategic planning and are intended to contribute to the preparation of a Comprehensive Koala Plan of Management for the coastal area of the Nambucca LGA.

1.1 Aims of the study

The main aims of the study were to:

- Assess and analysis historical records of koalas in the Nambucca LGA and determine areas of generational persistence of koalas
- Conduct systematic field surveys for koalas within the study area
- Analyse koala feed tree preferences
- Undertake mapping of koala habitat in the study area
- Evaluate threats to koalas in the study area, and
- Recommend management actions for the ongoing conservation of koalas in the Nambucca LGA

Each of the following sections deals with an aspect of the study, covering the methods, results and implications of that part of the study.

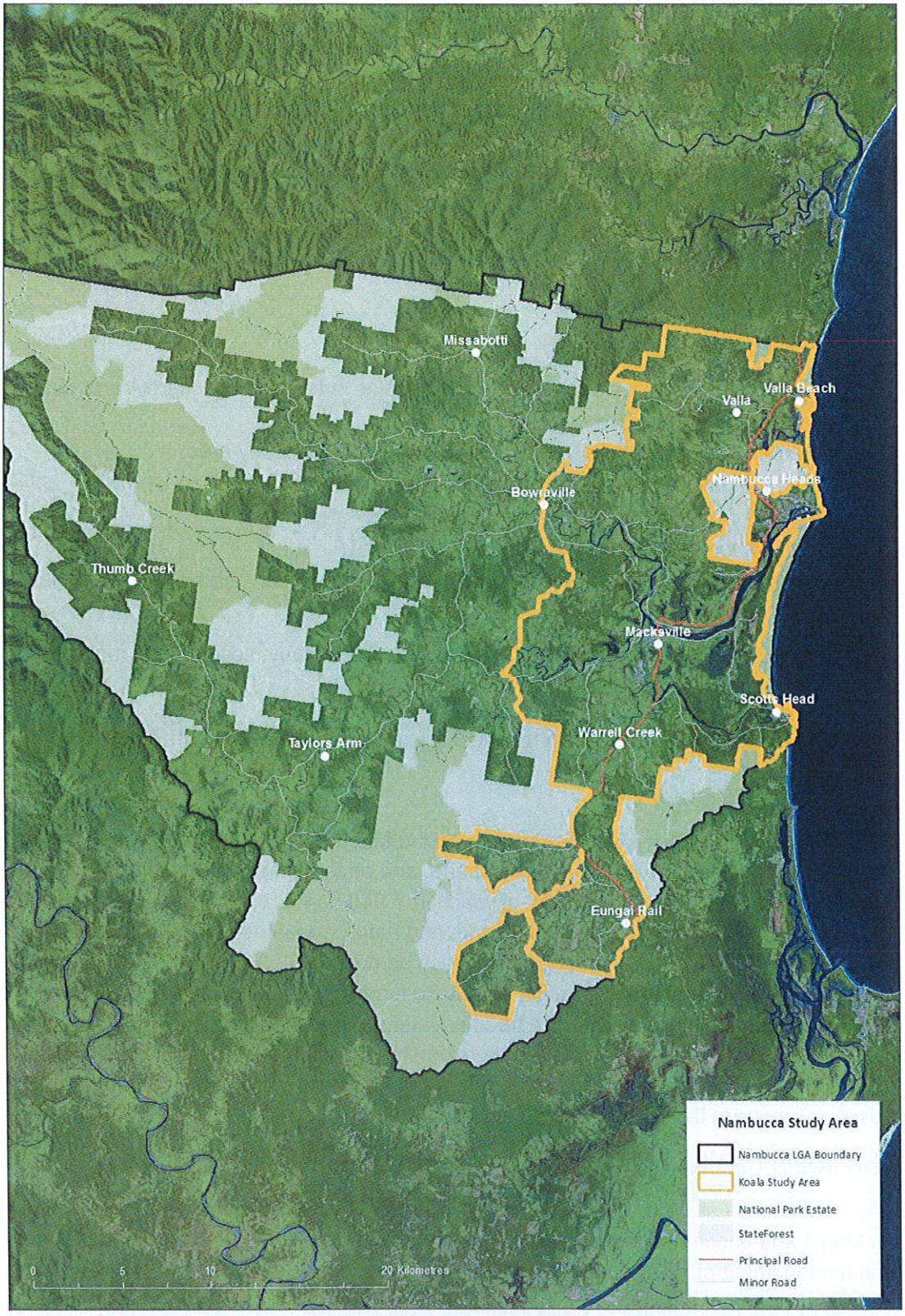
1.2 Description of the Nambucca LGA and koala habitat study area

The Nambucca LGA

The Nambucca LGA (see Map 1) is located on the Mid North Coast of New South Wales (NSW), midway between Sydney and Brisbane, and encompasses a total area of approximately 149 100 hectares (ha), of which 107 940 ha (72%) remains vegetated. This includes National Park Estate (national parks and nature reserves), which comprises 29 624 ha (20% of the LGA), State Forest Estate, which comprises 32 043 ha (21% of the LGA), and large areas of remnant vegetation on private lands, much of which is highly fragmented and disturbed (Map 1). Of the 86 174 ha of privately owned land, some 41 200 ha (47%) is cleared. The Nambucca LGA includes approximately 23 kilometres (km) of coastline and encompasses coastal floodplains, valley floors and coastal ranges in the east and the Great Eastern Ranges in the west.

The koala habitat study area

The koala habitat study area, in which core aspects of this study were conducted, is shown on Map 1 and encompasses the eastern, coastal zone of the LGA where potential threats to, and management of, koalas were more likely to be associated with activities and actions under the control of Nambucca Shire Council. It is an area of 36 301 ha of private land stretching along the coast and lying mainly east of the Great Eastern Range.



Map 1 The Nambucca LGA and koala habitat study area.

Although a number of community based studies (e.g. Lunney *et al.* 2009), opportunistic sightings (records from the Atlas of NSW Wildlife; see NSW BioNet, available at http://www.bionet.nsw.gov.au/) and more recent lineal surveys associated with the upgrade of the Pacific Highway (SKM 2010; GeoLINK 2013, 2014) have been undertaken within the study area, this report details the results of the first systematic field-based assessment of koala distribution in the coastal part of the LGA. Although this study undertook an assessment of all available koala records across all land tenures, the field-based assessment was primarily limited to private lands.

Vegetation mapping of the study area, undertaken by the Office of Environment and Heritage (OEH) in Coffs Harbour (OEH 2015), shows that only 17 463 ha (48%) of private lands remain vegetated and that much of this vegetation is highly fragmented or consists of small disturbed remnants. Cleared private land within the study area comprises18 838 ha (52%) and is primarily agricultural land associated with the Nambucca River valley and coastal floodplain, and associated valleys.

The study area (Map 1) contains and abuts areas of both State Forest and National Park Estate. To the north are Jagun and Valla Nature Reserves, Nunguu Mirral Aboriginal Area and Newry State Forest. In the north-west are Gladstone and Viewmont State Forests and Bollanolla Nature Reserve. To the east is Nambucca State Forest and along the coast, east of Warrell Creek, is East Gaagal Wanggaan National Park. In the south are Way Way and Tamban State Forests and Yarriabini National Park and, in the south-west, Ingalba State Forest.

Soils in the study area vary from fertile alluvial floodplain soils of the Nambucca River valleys through to the less fertile soils on the mid-slopes, hills and ridges of the coastal range. The geology of the Nambucca LGA is made up of slate, phyllite, schistose sandstone, schistose conglomerate and basic volcanics. Isolated outcrops of tertiary basalts, dolerite and minor trachyte occur at the headwaters of the Nambucca River. The remaining areas are generally alluvial, paludal and estuarine deposits consisting of sands, silts and gravels. Soils in the Valley consist mainly of lithosol and podsolic soils that may be commonly referred to as loam and clays (Baker *et al.* 1983, cited in Nambucca Shire Council 2006). These soils contain iron oxides that can be prone to form acid sulphate soils in areas subject to wetting and drying.

History

The Nambucca and Macksville area was historically occupied by two Koori groups, the Gumbaynggir to the north of the Nambucca River and the Dunghutti to the south, long before Europeans first arrived in the 1820s looking for Red Cedar and farming lands north of Kempsey.

The Gumbaynggir nation was estimated to cover an area of some 6000 square kilometres (Ryan 1988). It was thought that the Gumbaynggir people used koalas for food and for their skins and that local tribes were highly skilled at climbing trees, which allowed them to obtain honey, possums and koalas. Koalas are also prominent in mythologies in the local area, such as the legend of the great bear of Mount Yarrahapanni (Ryan 1988) and the legend of Ulitarra (Ryan 1988). Yarribini National Park, in the south-east of the study area, was named from the local Dunghutti and Ngambaa languages and means 'koala rolling down mountain'(OEH 2014b). The koala was thought to be a totemic animal for a number of tribes in the area (Ryan 1988).

The Nambucca area was first explored in 1820 by surveyor John Oxley, and cedar cutters were well established by 1840, with many pit sawyers operating along the Nambucca River by the mid-1840s. Cedar was hauled from the forests to the Nambucca River by teams of bullocks or horses, and shipped out via the river mouth. Shipbuilding and sawmilling were important early industries in the area and contributed greatly to the early clearing of the then vast forests. As well as major sawmills and shipyards at Nambucca Heads, sawmills were also located at Macksville, Valla, Bowraville, Eungai Rail and Bellwood. The main townships in the shire were established along the coast and rivers, reflecting the reliance on shipping as a means of transport.

As well as timber getting, much of the forest of the more fertile areas of the Nambucca Valley were ringbarked and cleared for farming. As more farming land was cleared, dairying was established as an emerging industry and the first butter factory in the valley opened at Macksville in 1902. However, the industry declined in the 1930s owing to soil depletion, the economic depression and a shift to grazing of beef cattle.

Other agricultural industries, including growing of tomatoes, bananas and carrots, developed in the area during the 1920s, particularly with the arrival, in 1923, of the railway. The mining of arsenical pyrites, molybdenite and antimony was carried out in the inter-war years.

Although dairying still continues to the present day, cattle grazing is the major agricultural land use within the study area. Forestry, which has been a traditional industry in the valley, continues in many areas although this resource is now less available and a number of timber mills have closed. Private native forestry remains a component of farm land use and income for some landholders. Rural land use in the study area is now a mix of traditional and non-traditional farming including many rural lifestyle allotments.

An ecological history of the koala in the Coffs Harbour area (Lunney *et al.* 2015) concludes that although koalas were widely distributed in the area, they appear never to have been as abundant as in other areas of the North Coast, such as eastern Lismore. This claim is supported by the scarcity of evidence of any large-scale koala fur trade and the sparse reporting of koalas by early explorers and surveyors of the area.

The historical clearing of the more fertile river flats, valley floors and coastal plains of the Nambucca LGA for agriculture combined with extensive and intensive logging since early settlement have led to the loss of koala habitat and food trees and have had a significant influence on the distribution and abundance of koalas throughout the area. These impacts would have displaced koalas from many of their traditional core areas of habitat leaving the steeper and, usually, less fertile mid-slopes and hills as the remaining refuge for the species. Although widespread hunting of koalas for pelts for export to England was undertaken in many areas of New South Wales (NSW) and Queensland in the late 1890s and early 1900s, anecdotal evidence suggests that such hunting was not common in the north coast, including the Nambucca LGA (Lunney *et al.* 2015).

1.3 Ecology of koalas

The koala is an iconic Australian species – a unique part of Australia's native wildlife of international significance. Koalas were originally distributed in coastal and subcoastal south-eastern and eastern Australia, from south-easternmost South Australia to northern Queensland, extending inland into central NSW and central Queensland. The distribution of koalas has now declined significantly, however, and remaining populations are scattered,

often at low densities, across a greatly reduced range. In some areas of Queensland and NSW, population declines of up to 80% and local extinctions have been documented (Environment and Communications Reference Committee 2011).

Koalas are known to feed primarily on a select number of eucalypt species in any one area, although they occasionally feed on a range of non-eucalypt species, including species of *Corymbia* (bloodwoods), *Melaleuca* (paperbarks) and *Allocasuarina* (she-oaks). The preference for species of feed tree may be influenced by a range of factors including region, season, leaf chemistry, elevation, temperature, water content and soil nutrients (Environment and Communications Reference Committee 2011). As the leaves of eucalypts are high in fibre but low in nutrients and protein (Ellis *et al.* 1999) koalas usually rest or sleep for most of the day and part of the night, and often only feed for periods of 2–4 hours a day. Koalas general behaviour of resting and sleeping for long periods is an adaptation to conserve energy (Cork *et al.* 2000).

Females koalas start to breed at about two years old and can potentially produce up to one joey a year. Births occur in spring and summer. Males do not become sexually mature until about three years old (Gall 1980) and the sex-ratio in a koala population is usually dominated by females. A dominant, alpha male will mate with several females (Gall 1980) although other roaming male koalas can also mate with a number of females in any population (Ellis *et al.* 2002). Koalas can live up to about 12 years of age in the wild but lifespan may be shorter in the presence of disease and other threats.

Young koalas usually disperse from their mother's home-range when they are between 1.5 and 3 years old (Dique *et al.* 2003). Dispersal of young occurs during the early part of the adult breeding season (McLean and Handasyde 2006) and young animals may travel many kilometres in search of suitable unoccupied habitat in which to settle. These dispersing koalas, which spend longer periods on the ground than established animals, are exposed to increased threats, such as car strike and predation.

The home-range of an adult koala varies with habitat quality (availability of suitable feed and shelter trees). Within the extent of the Pacific Highway upgrade in Bongil Bongil National Park, to the north of the Bellinger River, average home-range size was 15.7 ha for females and 30.6 ha for males. The largest home-ranges – of 53.6 and 69.7 ha – were for two large males whose home-ranges had been disturbed by construction activities (AMBS 2012). Smith and Andrews (1997), in a study in the former Pine Creek State Forest, recorded an average density of koalas across all forest types, including plantations, of 1 per 15 ha. This overall average was based on densities of 1 per 73 ha in plantation habitat, 1 per 14 ha in medium-quality habitat, and 1 per 12 ha in high-quality habitat. The size of home-ranges, although varying with habitat quality and disturbance, is likely to be similar to those of the above studies in most parts of the Nambucca study area.

Koalas rely primarily on the moisture within the leaves they eat for their daily water intake and there is some evidence (e.g. Ellis *et al.* 1995) that koalas may move into areas of higher soil moisture and microclimates, such as gullies and drainage lines, in times of high temperatures and drought, where trees with greater levels of leaf moisture are available. The reliance by koalas on a select number of species and individual trees within their home-range for foraging is not only linked to leaf-moisture levels but also to the levels of formyl phloroglucinol and phenolic compounds within the leaves that make many trees unpalatable (DECC 2008). Koalas may also use other non-feed trees (including non-eucalypts) for incidental browsing, resting or sheltering during cold weather or on hot days. They therefore

require a range of both food and non-food (shelter) trees in their habitat to cater for different seasons and weather extremes and for thermoregulation (Crowther *et al.* 2014).

Recent research of the quality of eucalypt forage across a numbers of sites in South Australian, Victoria, New South Wales and Queensland found significant positive relationships between densities of koalas and total nitrogen and available nitrogen in leaves. Available nitrogen is an integrated measure of the nutritional quality of leaves that evaluates the effects of leaf fibre and tannins (toxins) on the actual nitrogen that is available for digestion (Youngentob 2015). The use of individual trees by koalas across the landscape, however, remains a complex relationship between a number of variables, with factors other than just forage quality determining whether koalas will use particular trees.

Koala populations within NSW carry *Chlamydia* pathogens, the clinical signs of which are wet bottom (urogenital tract infection) and conjunctivitis. These signs are not always apparent or obvious in animals sighted in the wild. Chlamydia infection is often exacerbated when animals are exposed to high levels of stress associated with habitat disturbance, increased exposure to predators or extremes in environmental conditions, such as heat waves and drought. Koalas suffering from chlamydia can become weakened and more susceptible to threats, and in severe cases, may have reduced fertility or become infertile (DECC 2008). Chlamydia is present in the Mid North Coast population. Records from WIRES (NSW Wildlife Information, Rescue and Education Service Inc.; see http://www.wires.org.au/) in the Bellingen Shire, which borders Nambucca Shire, indicates that, of 66 koala rescues over the last eight years, 16 were for chlamydia, with eight of these animals subsequently euthanased (WIRES Bellingen, unpublished data). Available records from WIRES for the Nambucca Shire indicate only 10 animals rescued for the same period, with only one showing signs of chlamydia.

1.4 Legislative framework

The koala is listed as a Vulnerable species under the NSW *Threatened Species Conservation Act 1995* (*TSC Act*) and the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (*EPBC Act;* where listed as the combined populations of Queensland, New South Wales and the Australian Capital Territory).

Additionally, the koala is subject to the provisions of State Environmental Planning Policy No 44 – Koala Habitat Protection (SEPP 44) under the NSW *Environmental Planning and Assessment Act 1979* (*EPA Act*). The aim of SEPP 44 is 'to encourage the proper conservation and management of naturally vegetated areas that provide habitat for koalas to ensure a permanent free-ranging population over their present range and reverse the present trend of koala population decline:

- by requiring the preparation of plans of management before development consent can be granted in relation to areas of core koala habitat; and
- by encouraging the identification of areas of core koala habitat; and
- by encouraging the inclusion of areas of core koala habitat in environmental protection zones.'

Core koala habitat is defined in SEPP 44 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.'

Under the above legislation, there is a statutory responsibility on local government as the consent authority for development activities within an LGA to consider fully the likely impacts on koalas and their habitat of any proposed development.

The NSW *Native Vegetation Act 2003* regulates the clearing of native vegetation on private land. The Act permits minimal removal of native vegetation for the purposes of Routine Agricultural Management Activities (RAMAs). Clearing other than that permitted under a RAMA requires a Property Vegetation Plan (PVP) to be approved for that property. Private Native Forestry (PNF) is also regulated through the *Native Vegetation Act* and requires the approval of a PVP for the property. Where a PVP is approved, PNF can be undertaken in accordance with the PNF Code of Practice. PNF however is not permitted in any area identified as core koala habitat within the meaning of SEPP 44.

The NSW *Companion Animals Act 1998* requires the proper management of dogs to ensure they are under the control of a competent person when in public places, and that dogs must not be allowed to roam or attack other people, animals and wildlife. The *Companion Animals Act* provides for the preparation of a Local Companion Animals Management Plan that enables councils to fulfil their responsibilities by determining appropriate rules for dog ownership and areas for dog release, exercise and exclusion.

2 Historical records of koalas in the Nambucca LGA and study area

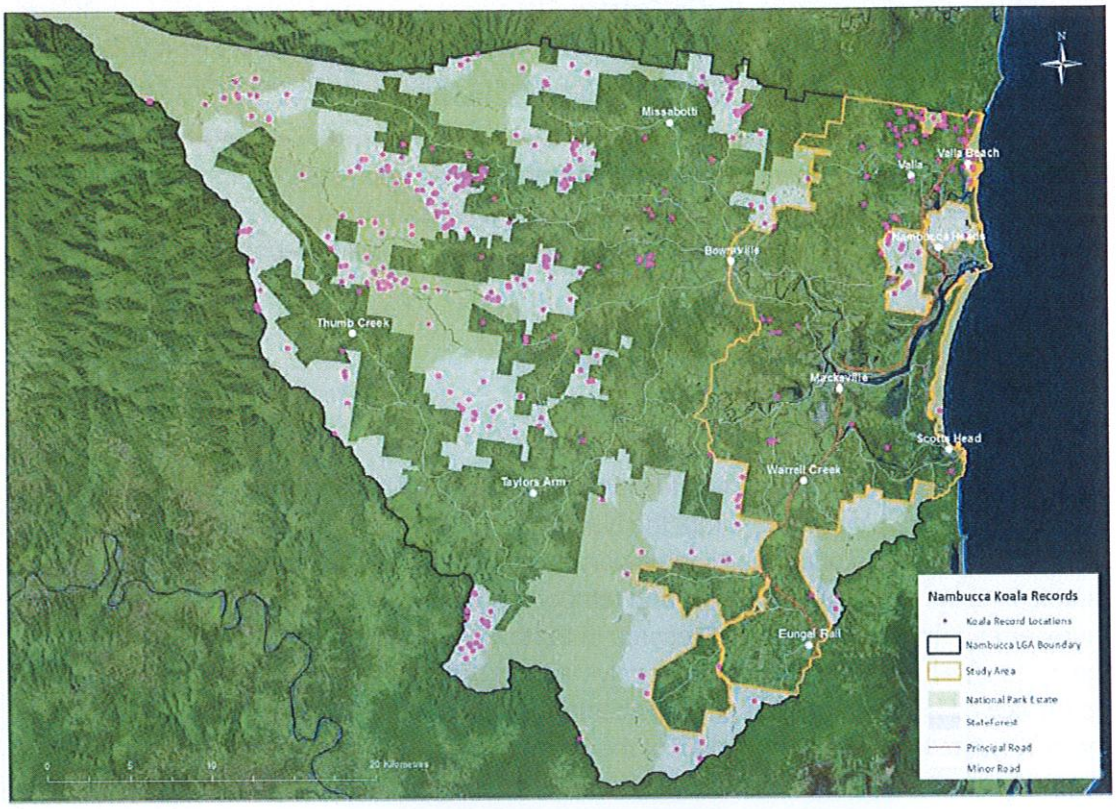
2.1 Introduction

Because the koala is an iconic Australian species with a high public profile and which is readily identified and largely unmistakable, reporting rates of koalas across the landscape are usually much higher than those for other threatened species. Records, however, although providing an important indication of where koalas occur, tend to be biased towards areas with higher human population densities, especially opportunistic records. In a community-based study in NSW, most records (sightings) were within 2.5 km of an observer's home and few records were more than 10 km from a dwelling (Lunney *et al.* 2009). This implies that in rural areas where properties tend to be 40 ha or larger, reporting rates for koalas are likely to be significantly lower than in areas with denser human populations. Koalas in less populated areas with larger rural properties can therefore go unreported and false negatives of occurrence (i.e. no animals reported when in fact they occur) recorded.

Historical records of koalas for the Nambucca LGA were primarily obtained from the OEH's Atlas of NSW Wildlife (see NSW BioNet, available at http://www.bionet.nsw.gov.au/). Overall, 860 records of koalas were available for the Nambucca LGA for the period 1950 to 2014; 716 of these records were from State Forest Estate. Two state-wide, community-based surveys of koalas, in which the Nambucca LGA was included, have also been undertaken (Lunney *et al.* 2009), with records in the Atlas of NSW Wildlife. After removing duplicate and unreliable records, a total of 498 valid records was used for the analysis in this report. Of these 498 records, 326 were in current State Forest Estate and 122 on current private (freehold) land; and 39 were from community surveys (Lunney *et al.* 2009), 2 from OEH Wildcount surveys (see http://www.environment.nsw.gov.au/animals/wildcount.htm), and 9 from surveys associated with the upgrade of the Pacific Highway (NSW Roads & Maritime Services).

The distribution of all valid koala records in the Nambucca LGA is shown on Map 2. Most records are in the western part of the Nambucca LGA, within State Forest and National Parks Estate and outside the koala habitat study area. The large numbers of records in this area are mainly from targeted surveys on public lands. Another cluster of records are on private land in the north-eastern part of the Nambucca LGA, north and west of the town of Nambucca and near Valla and to the west of there.

There are a number of records to the immediate north of the study area and south of the Bellinger River, in the Bellingen Shire. These records adjoin the cluster of records in the study area around Valla. A number of records indicate that a breeding population of koalas persists in and north of Valla area, including a record of a young koala rescued from the beach north of Valla in 2013 (Elizabeth Mulligan, personal communication; Figure 1), a record of a koala in Jagun Nature Reserve in November 2014 (Lori Warren, OEH, personal communication; Figure 2), a record of a young koala in Valla Nature Reserve in 2015 (NSW NPWS unpublished survey data) and a record of a koala and joey south of Hungry Head sighted in 2013 and in 2014 respectively.



Map 2 Records of koalas throughout the Nambucca LGA.

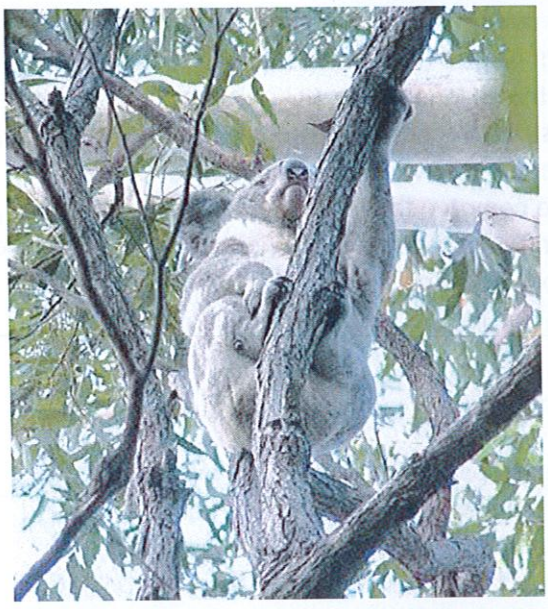


Figure 1 Koala sighted in Jagan Nature Reserve, November 2014. (Photo: Lori Warren)

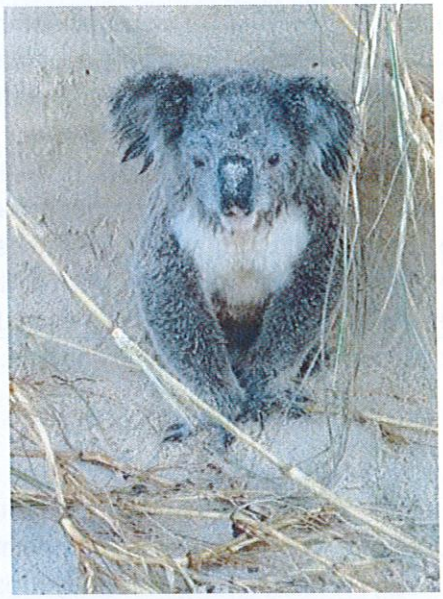


Figure 2 Koala rescued from Valla Beach, June 2013. (Photo: Elizabeth Mulligan)

A road-killed koala was recorded in October 2014 on the Pacific Highway north of Ballards Road (J. Turbill, personal communication), in the Bellingen Shire, and a koala was recorded near Ballards Road (RMS, unpublished data) during clearing in Newry State Forest for the Pacific Highway upgrade.

Elsewhere in the LGA, there are sparsely distributed records in the south and south-west of the koala habitat study area, on both private land and State Forest and National Park Estate, and there are only a few older records south of the Nambucca River and east of the Pacific Highway.

2.2 Assessment of historical records

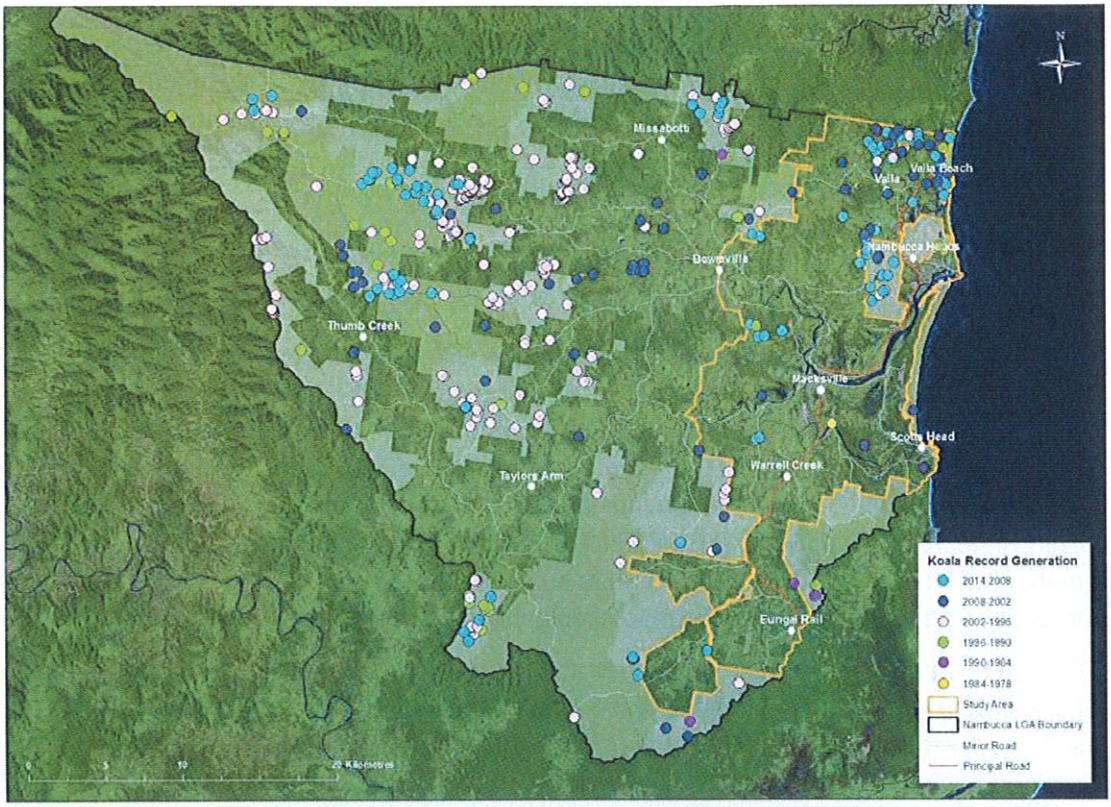
Analysis of records

An analysis to determine broad trends in the geographical distribution of koalas over time was undertaken using records from the Nambucca LGA as a whole. The aim of the analysis was to determine historical and contemporary population centres and distribution of koalas and to indicate any regional spatial and temporal population trends. As a result of the low number and distributional bias of records in State Forest and National Park Estate, the analysis of records was not comprehensive across the total landscape and therefore needs to be viewed as indicative rather than absolute. Given these constraints the analysis does, however, provide a broad indication of the distribution of koalas over time (Map 3) and supports the findings of the field surveys undertaken as part of the wider study (see Section 3). The map of generational persistence (Map 4) provides an overall view of where koalas are persisting over a number of koala generations.

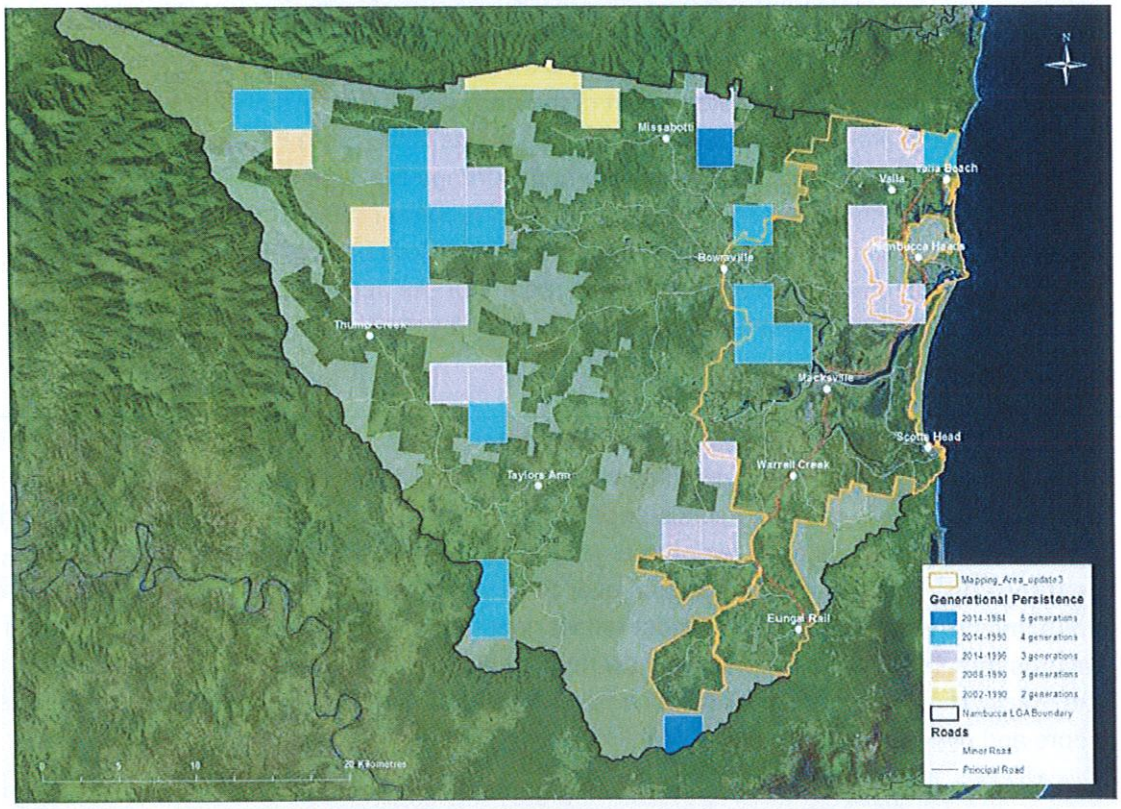
The 498 valid records were sorted into chronological order and assigned to the last six (6) koala generational periods from 1978 to 2014. A koala generation is defined as a period of six years (Phillips 2000). The usual method for determining koala generation persistence uses the International Union for Conservation of Nature (IUCN) criteria for assessing perceived population declines over a period of three generations (IUCN Standards and Petitions Subcommittee 2010). However, it was not practical to do so for this study given the lack of records (49) in the periods 1978–1996 compared with the later periods 1996–2014 (447 records). As a result, it was not possible to compare these two time periods statistically or spatially. To allow an assessment to be undertaken records in the periods going back five generational periods was undertaken and periods showing a generational persistence of 12 years or greater were mapped. Given that only one record exists in the period 1978–1984 this period was omitted from the analysis.

Generational persistence across the Nambucca LGA

Generational persistence analysis, which assesses persistence of koalas in areas where have been recorded over numbers of generational lifespans, was used to help understand the long-term persistence of koala populations across the Nambucca LGA and, more specifically, in the koala habitat study area. Analysis was done by overlaying a 2.5-km grid over the Nambucca LGA (which includes the koala study area) and then noting where records for each generation of koalas (6-year periods over the last six generations) are represented (based on Phillips 2000). From this assessment, grid-cells where records of koalas occur for a number of generational periods were identified. Results using a number of generational periods, from two generations (12 years), three generations (18 years), four



Map 3 **Records of koala generations in the Nambucca LGA.**



Map 4 **Koala generational persistence in the Nambucca LGA.**

generations (24 years) and five generations (up to 30 years) were used across the LGA to map persistence of koalas (Map 4) . Koala persistence over a number of generational periods provides an indication of where koala populations have been recorded in the landscape over time. The cells indicate both key areas of continual occupation by koalas and a regional indication of distribution.

2.3 Results

Analysis of records

Records of koalas in the Nambucca LGA, although widely distributed, are concentrated in the north-east, around Valla and to the west of there, and in the west of the LGA, in National Park and State Forest Estate. There are few records in the extensively cleared central parts of the Nambucca LGA. In the south, records are again restricted mostly to areas of State Forest Estate with few records on private land. The greater number of records in clusters within State Forest and National Park Estate do not necessarily represent greater use or numbers of koalas in those areas, because surveys have not been conducted systematically throughout the region and are biased to sites subject to pre-harvest forestry assessment.

Given the overall small number of records and the bias of records to public lands an analysis of the area of extent and occupancy of the koala population was not undertaken. However, as shown by the distribution of records (Map 2) it can be seen that koalas generally occur throughout most of the Nambucca LGA with the exception of the areas south of the Nambucca River and east of the Pacific Highway. There are almost no records within that area.

The chronological distribution in Figure 3 shows that the bulk of records (275 records) were collected during 1996–2002, which represents the results of extensive fauna surveys undertaken in State Forest Estate as part of the analysis for the Regional Forestry Agreements and pre-harvest surveys conducted at this time (State Forests of NSW Environmental Impact Statement, Coffs Harbour–Urunga Management Areas). The period 2008–2014 contains the second highest number of records (109 records: 56 within State Forest Estate, 53 in other tenures). There are fewer records before 1996, with only 43 for 1990–1996, five for 1984–1990 and a single record for the period 1979–1984. Figure 3 shows the chronological distribution of records in six 6-year generational periods.

Generational persistence

Map 4 shows cells where koalas have persisted over generations in the LGA. Between 1984 and 2014, only two cells were identified where koala activity was recorded over five koala generations; 17 cells recorded persistence over four generational periods (1990–2014) and 18 cells recorded persistence over three generational periods (1996–2014). A further two cells recorded generational persistence over three generations (1990–2008), but there were no records in these cells from the most recent generation. There are some areas with older records (pre-1995) where koalas are now thought not to occur. These include areas east of the Pacific Highway south of Nambucca River to Warrell Creek and the mostly cleared valley floors and river floodplains west of Macksville.

In the koala study area the locations showing generational persistence generally correspond with areas shown by the koala habitat surveys (see section 3: Koala field surveys) to support koalas, such as areas east and west of Valla. However, there are other areas in the south-

west of the koala study area (e.g. west of Eungai Rail) where koalas were recorded during the surveys but there are no historical records. Koalas are likely to have persisted in these areas for some time and this result highlights the inconsistency in historical reporting of koalas across the study area (i.e. koalas have been present but there are no records in the databases used). For this reason, the location and dates of koala records, specifically the absence of a record, should be interpreted in the context of other survey results.

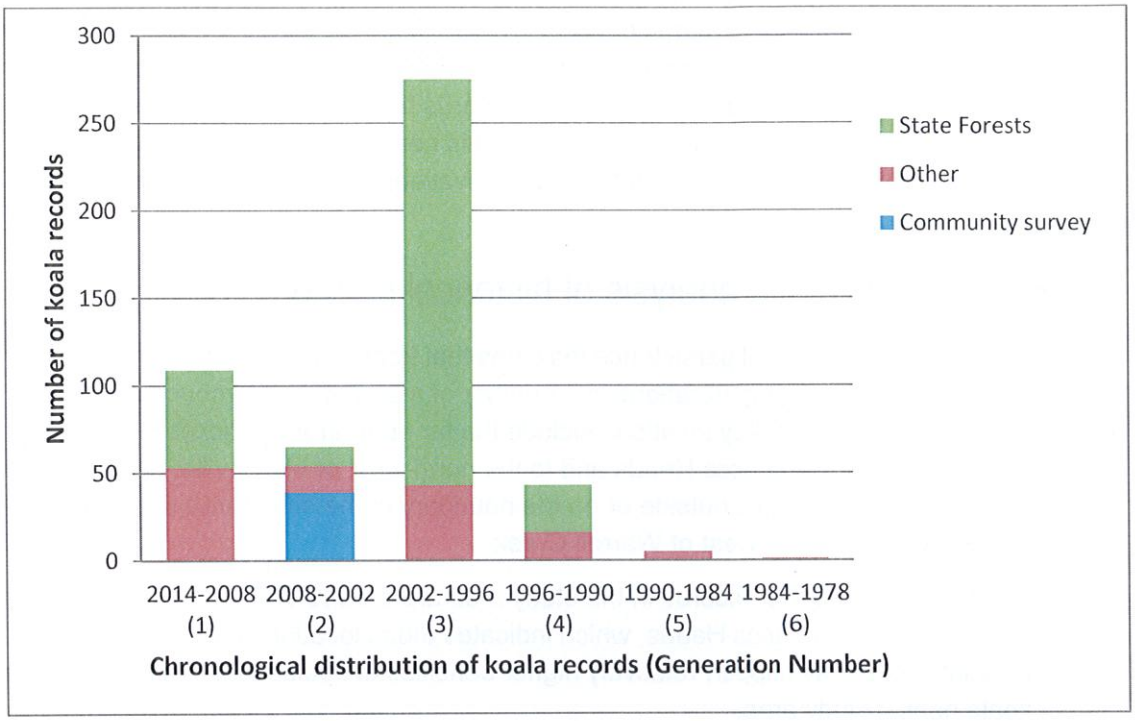


Figure 3 Chronological distribution of all valid koala records 1978–2014 in six 6-year generational periods (indicated in parentheses) from 498 valid records (excluding duplicate and unreliable records). The source of records is indicated by the key: State Forests = surveys conducted by State Forests of NSW on State Forest Estate; Community survey = community records across all tenures; and Other = other records on all tenures except State Forest Estate.

The generational persistence analysis highlights the difference in historical records and koala occupation between the areas in the north and north-east of the Nambucca LGA and areas south of the Nambucca River. Although there are many records in the north of the Nambucca LGA, the analysis indicates that, although widespread south of the Nambucca River, there are few reports of koalas in this area. In the area east of Macksville, including west of Scotts Head, it now appears koalas are absent or in extremely low numbers. Without intervention, the viability of any population in these areas is considered low.

The persistence of koala populations in the west of the Nambucca LGA, in State Forest and National Park Estate, in areas west and north of Nambucca Heads and Valla, and in three cells in the south-west of the study area (Map 4) is also supported by field surveys (see below). There is an absence of continuous koala records in the last three koala generations in the areas to the south-west of Picket Hill and the Newry Creek area and this result needs further research as koalas possibly persist in these areas.

The assessment of historical koala records for the study area does provide an indication of where koalas are distributed throughout the landscape, where koala populations have persisted over time, and where koalas are no longer being recorded. However, this assessment needs to be evaluated against the significant limitations of the available data. As in other areas of the north coast, the number and locations of koala records for the Nambucca LGA and within the study area are influenced by the type of land tenure, where there are often more records on public lands, such as state forests where surveys have been undertaken. Records are also more likely reported on private land in more populated areas which have smaller properties (in terms of area). In their study based on community records, Lunney *et al.* (2009) noted few reports of koalas more than 10 km from a dwelling. As a result, the possibility of false negatives (where no records have been submitted but koalas actually occur) may influence the above results and this needs to be considered in interpreting the findings of the spatial analysis of the available records and the generational persistence map.

2.4 Key findings of the analysis of historical records

- Analysis of generational persistence indicates that koalas have been continuously recorded for up to five generations in a number of areas of the Nambucca LGA. Within the study area, key locations include the far north around Picket Hill and west of Valla, west of Nambucca Heads and to the north-west of Macksville. Other areas of significance occur just outside or on the boundary of the study area south-west of Eungai Rail and to the west of Warrell Creek.
- The highest number of records in the study area are around Valla and Picket Hill and to the west of Nambucca Heads, which indicates those locations may be important for koalas and may support relatively higher densities of koalas than elsewhere in the koala habitat study area.
- There are few records of koalas south and east of Macksville or in the western Scotts Head area and most of these records are more than 20 years old, indicating that koalas may no longer occur in the area or populations in these areas are very low and unviable.
- Recent records east of the highway in Valla and north of Valla indicate the presence of a small population that links to the north and west with populations in Newry State Forest. The long-term viability of this population requires investigation.
- Outside the study area, in the western part of the Nambucca LGA, the generational persistence analysis shows that areas of vegetated lands to the north of Thumb Creek, including Gumbaynggirr National Park, Dunggir National Park, Gumbaynggirr State Conservation Area, Buckra Bendinni State Forest and Mistake State Forest, have records persisting over four koala generations.
- Areas north-east of Missabotti have one grid-cell showing five koala generations and one grid cell of three generations in Gladstone State Forest and Bowraville Nature Reserve.

3 Koala field surveys

3.1 Introduction

Within the Nambucca LGA, most records of koalas are from state forests, where systematic surveys are a requirement before logging occurs. There are also a large number of records within national parks and areas of suitable habitat associated with greater human population density, such as rural residential areas. Although populations of koalas may still occur in areas of low human population density (i.e. larger rural allotments), the likelihood of detection is much lower in these areas. In order to get a better understanding of habitat use by koalas throughout the study area, a systematic field survey of koalas was undertaken to sample forested private-tenure lands and to supplement the historical koala records and provide information on the distribution of koalas populations at the landscape scale.

3.2 Study area

Surveys sites were positioned using a systematic grid-pattern across the study area (Map 1; see below) to ensure all areas and potential forested habitat were sampled. Survey sites were primarily located on private lands although a small number were in other tenures, such as Crown Road Reserves.

Further, for a better understanding and interpretation of the survey results and for management purposes the study area was then separated into three precincts (Map 5):

- **Precinct 1:** the area north of Taylors Arm and Nambucca River
- **Precinct 2:** south of Taylors Arm and Nambucca River and west of the Pacific Highway
- **Precinct 3:** south of the Nambucca River and east of the Pacific Highway.

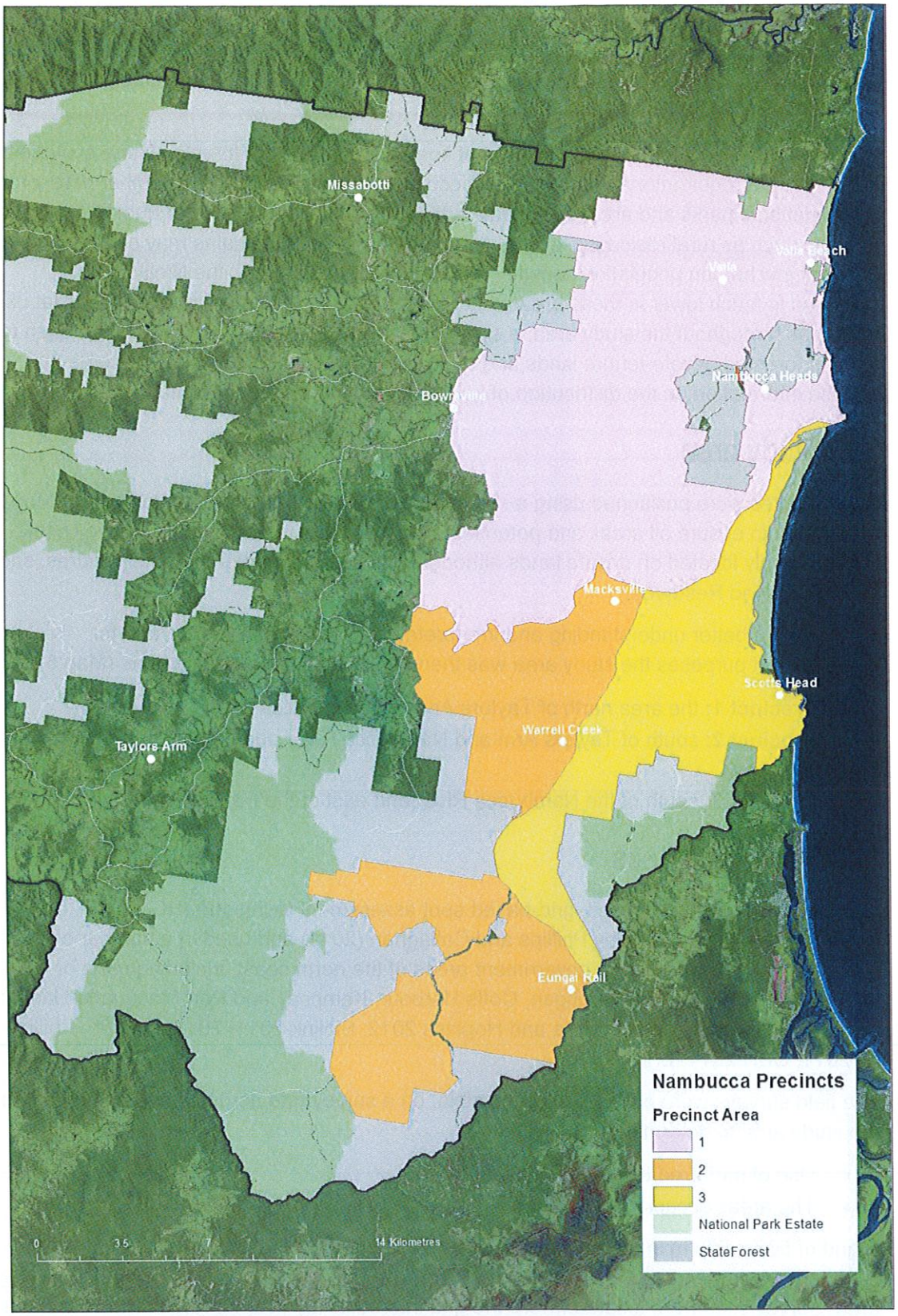
3.3 Survey methods

The survey used a regularised, grid-based spot assessment technique (RG-bSAT), based on the methods developed by Phillips and Callaghan (2011) and used in a number of koala surveys in parts of other local government areas of the north coast, including parts or all of the Tweed, Byron, Ballina, Bellingen, Coffs Harbour, Kempsey and Port Macquarie-Hastings LGAs (Lunney *et al.* 1999; Phillips and Hopkins 2012; Biolink 2011, 2013a, 2013b; Phillips *et al.* 2011; OEH 2014a).

The field surveys were based, where possible, on a survey grid across the forested parts of the study area to determine:

- Use of preferred trees by koalas, and
- The areas occupied by koalas

A grid of 500 × 500 m in the north of the study area and 1000 × 1000m in the south of the study area (north and south of Nambucca River respectively) was overlaid across the study area. Survey sites were located where the grid intersects lay over forested areas containing potential koala habitat, the latter based on high-resolution digital aerial photography (ADS 40 Digital Image Acquisition System, with 50-cm resolution; NSW Land and Property Using this



Map 5 **The three management precincts of the koala habitat study area.**

Information). method, survey sites were identified in suitable habitat across the whole study area. Sites where vegetation was deemed unsuitable habitat, or were inaccessible or too difficult to survey (i.e. steep, weed infected or heavily disturbed) were excluded. The delineated survey sites were then identified to a property scale and a letter from Nambucca Shire Council was sent to each landholder seeking permission to undertake a survey on their land. Surveys were only undertaken where landholder permission was obtained. Surveys were conducted between October 2014 and March 2014, and 126 of a potential 300 sites were surveyed.

Surveys sites were located in the field using a GPS and in some cases were moved in the field where access was too difficult or to sample more suitable habitat.

At each survey site, 25–30 trees greater than 15 cm diameter at breast height (dbh) were sampled for the presence of koalas and koala faecal pellets (scats). For fuller details of the survey sampling method (Spot Assessment Technique (SAT)), see Phillips and Callaghan (2011). At each site a central tree was selected (where possible a koala feed-tree species) and a search for koala scats was made around the base of the 25 trees with a dbh of 15 cm or greater closest to the start tree. Searches involved scanning the ground or leaf-litter surface for scats, mainly within 1 m of the base of the tree and under the drip line of the canopy, before then searching in and beneath the leaf-litter, with a minimum total effort of 2 person-minutes per tree. A search for koalas in all trees within a 25-m radius of the central start tree was also undertaken. If a koala scat was recorded under any of the first 25 trees searched then another five trees were searched, and a 1-ha search was undertaken to look for koalas within a transect 40 m wide × 250-m long, which was generally located parallel to the slope and starting at the central start tree. The aim of the 25-m radius and transect searches was to enable determination of area-based estimates of koala density.

At each site, koala activity was calculated by dividing the number of trees with a koala scat underneath it by the total number of trees searched at the site (i.e. 30) and multiplying this by 100 to give a percentage usage.

To allow an analysis of koala activity derived from this study against those recorded in the literature for other areas the category of 'East Coast (low) – 'Medium (normal) Use' for population density activity thresholds was used (refer to threshold percentages derived by Phillips and Callaghan 2011). These activity levels are shown in Table 1 below.

Table 1 Categorisation of Low, Medium (Normal) and High use koala activity. Categories are based on use of mean activity levels ± 99% confidence intervals (nearest percentage equivalents) for each of three area – population density categories (based on Phillips and Callaghan 2011).

Area (density)	Activity category		
	Low use	Medium (Normal) use	High use
East Coast (low)	–	**≥3.33% but ≤12.59%**	**>12.59%**
East Coast (medium–high)	<22.52%	≥22.52% but ≤32.84%	>32.84%
Western Plains (medium–high)	<35.84%	≥35.84% but ≤46.72%	>46.72%

Preferred koala food trees

In any one area, koalas are fairly selective in the trees they use for food and shelter. The primary and secondary food trees usually comprise a small number of species, mostly species of *Eucalyptus*, combined with a number of additional eucalypt and non-eucalypt tree species that are occasionally browsed or used for shelter and resting. The NSW koala recovery plan (DECC 2008) provides a comprehensive list of koala food trees in each of the seven koala management areas of the state (Appendix 2 in DECC 2008). Eucalypt tree species in this list that occur in the Nambucca area include the primary food species Tallowwood (*Eucalyptus microcorys*), Forest Red Gum (*Eucalyptus tereticornis*) and Swamp Mahogany (*Eucalyptus robusta*); secondary food tree species include Small-fruited Grey Gum (*Eucalyptus propinqua*) and Red Mahogany (*Eucalyptus resinifera*). Other species of food trees identified in studies on the north coast include Sydney Blue Gum (*Eucalyptus signata*), Flooded Gum (*Eucalyptus grandis*) and Forest Oak (*Allocasuarina torulosa*).

The identification of specific tree species favoured by koalas for a regional area can be problematic given the varied geological and soil landscapes and the often complex mix of vegetation communities that result. Together with other factors, such as the fragmentation of habitat, leaving only remnants, edge effects and the often disturbed nature of vegetation floristic diversity from past clearing, forestry, fire and associated weed invasion, defining and mapping koala habitat can be challenging.

Site topography, soil moisture and soil nutrient status are also recognised as key drivers in determining potential habitat quality and carrying capacity for koalas (Phillips and Callaghan 2000; Moore and Foley 2005). The availability of nitrogen and level of toxins in the leaf of individual trees also influences the selection of trees by koalas.

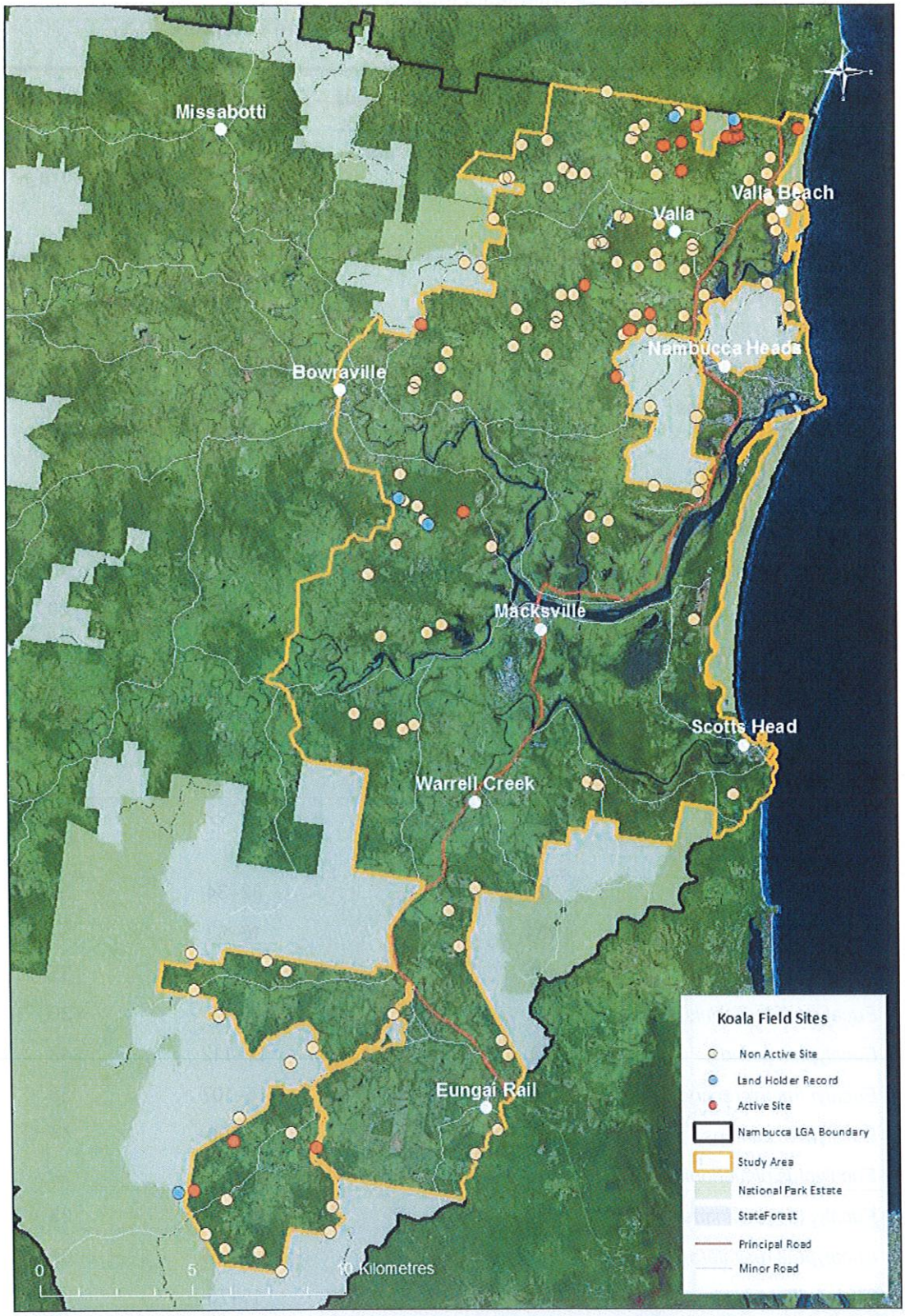
As part of the study, the species of tree for which activity was recorded during surveys was analysed.

3.4 Results

Koala site surveys

In total, 126 sites were surveyed between October 2014 and March 2015 (Map 6). Koala activity, as indicated by a koala scat beneath one or more trees, was recorded at only 15 sites. A total of 3295 trees were sampled, with one or more scats beneath 20 individual trees. Scats were recorded beneath another four trees outside the targeted survey sites. No koalas were observed at any of the survey sites or during the 1-ha transects. Table 2 provides a summary of all tree species sampled, including opportunistic findings of additional trees, those trees with scats recorded, minimum and maximum tree diameter and average diameter.

It was not possible to determine population estimates for any areas given the low koala activity levels and the fact that no koalas were sighted during the field surveys within the 25-m radius and 1-ha transect searches.



Map 6 Koala field-survey sites within the koala study area, showing sites where koala activity was recorded during the field surveys or records of landholders.

Table 2 Summary of all tree species sampled, the number at which scats recorded, and minimum, maximum and average diameter of all trees sampled.

Tree species	Number of trees sampled	Number of trees with scats	Tree diameter at breast height (cm)	
			Range (minimum – maximum)	Average
Acacia melanoxylon	13		15–31	21
Acacia spp.	5		17–36	21
Allocasuarina littoralis	1		16	–
Allocasuarina torulosa	273		15–67	23
Alphitonia excelsa	15		15–42	24
Angophora costata	15	1	15–69	35
Banksia integrifolia	9		15–56	31
Callicoma serratifolia	11		15–27	18
Callistemon salignus	28		15–44	20
Casuarina glauca	13		15–48	26
Cinnamomum camphora	2		32–38	35
Corymbia gummifera	14		16–58	34
Corymbia intermedia	203		15–115	37
Corymbia maculata	48	1	16–63	34
Elaeocarpus reticulatus	1		19	–
Endiandra sieberi	2		32–34	33
Eucalyptus acmenoides	134		16–82	37
Eucalyptus carnea	60		15–109	35
Eucalyptus fusiformis	3		28–32	30
Eucalyptus grandis	79		17–112	43
Eucalyptus microcorys	857	13	15–107	38
Eucalyptus pilularis	266		15–200+	44
Eucalyptus planchoniana	1		53	–
Eucalyptus propinqua	320	2	15–114	33
Eucalyptus resinifera	96	1	15–126	37
Eucalyptus robusta	73	1	15–75	37
Eucalyptus saligna	57		12–128	43
Eucalyptus siderophloia	174		21–846	35
Eucalyptus signata	3		22–40	33

Tree species	Number of trees sampled	Number of trees with scats	Tree diameter at breast height (cm)	
			Range (minimum – maximum)	Average
Eucalyptus tereticornis	16	1	15–60	38
Unidentified stringybark eucalypts	3		25–31	29
Glochidion ferdinandi	5		15–40	23
Guioa semiglauca	1		15	–
Jagera pseudorhus	1		25	–
Lophostemon confertus	58		15–99	35
Lophostemon suaveolens	10		15–65	26
Melaleuca nodosa	1		20	–
Melaleuca quinquenervia	63		15–86	29
Melaleuca sieberi	7		16–33	22
Melaleuca sp.	1		21	–
Melia azedarach	1		30	–
Notelaea spp.	1		19	–
Rainforest species	7		15–28	24
Rhodamnia spp.	3		16–19	17
Syncarpia glomulifera	339		15–105	32
Tristaniopsis laurina	1		17	–
Trochocarpa laurina	1		15	–
Waterhousea floribunda	1		34	–
TOTAL	3295	20		29

Koala activity levels

Koala activity levels for all sites that recorded scats were proportioned into three categories, 3.33% to <6.66%, ≥6.66% to <10% and ≥10%. Of the active sites, activity levels of 3.33% to <6.66% were recorded at 11, activity levels of ≥6.66% to <10% at three, and an activity level ≥10% at one site. These site-activity categories are shown on Map 7 and spatially delineate important areas that support resident koala populations. The derived activity levels fit within the 'East Coast (low) – Medium (Normal) Use' activity category threshold proposed by Phillips and Callaghan (2011; see Table 1).

Map 7 Activity levels at sites where koala activity was recorded within the koala habitat study area.

Study area precincts

As discussed above, to better understand the results of the field surveys and for management purposes the study area was separated into three precincts (Map 5; see above), each of which is discussed below.

Precinct 1 – North of the Nambucca River

A total of 92 sites was surveyed in Precinct 1 (Map 5) and activity, as indicated by the presence of koala scats, was recorded at 11 sites and at 16 trees (see Table 3). No koalas were observed within the 25-m radius or the 1-ha transect searches. Koala activity levels for the 12 active sites ranged from 3.33% to 10% with an average for all sites of 4.8%. Table 3 shows details of sites at which activity recorded in Precinct 1, activity levels, the tree species beneath which scats were recorded and the diameter at breast height of trees at which activity recorded.

Table 3 Summary of sites at which koala activity was detected, the site activity, species of tree at which scats recorded and diameter at breast height (dbh, in cm) of trees with scats.

Site code	Site activity (%)	Number of trees with scats	Species of tree (dbh in cm)
Precinct 1			
N42N	6.66	2	*Eucalyptus microcorys* (33, 25)
N43N	6.66	2	*Eucalyptus microcorys* (23), *Eucalyptus tereticornis* (25)
N56N	3.33	1	*Eucalyptus microcorys* (63)
N57N	3.33	1	*Eucalyptus microcorys* (46)
N59N	10.00	3	*Eucalyptus microcorys* (60, 68), *E. propinqua* (57)
N61N	6.66	2	*Eucalyptus robusta* (42), *E. microcorys* (44)
N89N	3.33	1	*Eucalyptus propinqua* (44)
N151N	3.33	1	*Angophora costata* (36)
N165N	3.33	1	*Eucalyptus microcorys* (46)
N176N	3.33	1	*Eucalyptus resinifera* (30)
N186N	3.33	1	*Eucalyptus microcorys* (72)
N217N	3.33	1	*Eucalyptus microcorys* (42)
Average	**4.80**		
Precinct 2			
N293N	3.33	1	*Corymbia maculata* (24)
N297N	3.33	1	*Eucalyptus microcorys* (29)
N300N	3.33	1	*Eucalyptus microcorys* (34)
Average	**3.33**		

Active sites were spread across the forested areas of Precinct 1, from west of Picket Hill and Newry Creek up to the northern boundary of the LGA and east to Valla on the coast. In addition to the 12 active sites surveyed, four opportunistic records of scats were noted in this precinct during the survey. Four landholders also reported recent sightings of koalas (seen or heard) in their properties. Only one active site was east of the Pacific Highway, in the Valla area. However two recent sightings of koalas have been recorded in this location, one in Valla Nature Reserve and one in Jagan Nature Reserve (see section 2).

Recent surveys undertaken as part of the Pacific Highway upgrade recorded koala activity at a number of sites in Nambucca State Forest (GeoLink 2013, 2014.). These additional sites are on public land, which was not a focus for the field surveys in this study. However, these records and the recent records mentioned in the preceding paragraph provide evidence of the persistence of koalas in this area.

Precinct 2 – South of Nambucca River and west of the Pacific Highway

A total of 24 sites was surveyed in Precinct 2, although six of these sites were on public land just beyond the boundary of the precinct owing to difficulties in obtaining access to private land near these sites. Activity was recorded at only three sites within Precinct 2 and no koalas were observed within the 25-m radius or 1-ha transect searches. Activity levels for the four active sites were low (3.33% for all sites). Table 3 shows details of sites at which activity was recorded in the precinct.

A local resident also reported seeing a koala in Tamban State Forest in 2012 and had heard koalas in the same area over the last few years.

Precinct 3 – South of Nambucca River and east of the Pacific Highway

A total of 10 sites was surveyed in Precinct 3, with no activity recorded. There have also not been any reliable records of koalas in this precinct since the 1990s. Landholders in this area had not seen or heard koalas for decades and one long-term resident landowner reported that the last koala he had sighted was in the 1960s (Charlie Barber, personal communication).

Preferred koala food trees in the study area

In total, 3295 trees – 2145 *Eucalyptus* species and 1150 non-eucalypt species – were sampled at the 126 surveys sites. Activity was recorded at only 15 of the 126 sites and scats found under only 20 individual trees. An additional four scats where found opportunistically during the surveys. At the active sites, scats were found beneath five different species of eucalypt and two non-eucalypt species (Table 4). Scat counts were significantly higher beneath Tallowwood (65% of all trees with scats) than the other six species (5–10% for each species).

For each tree species sampled that recorded one or more scats, a proportional index of utilisation, referred to as a tree species 'strike rate' (P) was obtained by dividing the number of trees of a species with a scat by the number of trees of that species (based on the methodology developed by Dr Steve Phillips, Biolink Ecological Consultants, Uki). The summary of tree usage in Table 3 and corresponding strike rate for species in Table 4 shows the significance of Tallowwood (*Eucalyptus microcorys*) and, to lesser degree, Small-fruited Grey Gum (*E. propinqua*). Scats were only found under one or two individuals for all other

species. Of the four opportunistic observations of scats, three were under Tallowwood and one under a Sydney Blue Gum (*Eucalyptus saligna*).

Table 4 Summary of tree species surveyed at sites where koala activity recorded (note that activity not recorded for all species). P = strike rate (the number of trees of a species with a scat divided by the number of trees of that species); SE = standard error.

Species	Number of trees	Number of active sites at which tree species recorded (total number of active sites =15)	Number of scats found	Proportion of total number of scats (*n* = 20)	P ± SE
Acacia spp.	1	1			0
Allocasuarina torulosa	41	9			0
Alphitonia excelsa	1	1			0
Angophora costata	3	1	1	5%	0.333 ± 0.272
Callistemon salignus	1	1			0
Corymbia intermedia	26	11			0
Corymbia maculata	2	1	1	5%	0.500 ± 0.354
Elaeocarpus reticulatus	1	1			0
Eucalyptus acmenoides	7	2			0
Eucalyptus carnea	6	2			0
Eucalyptus grandis	2	2			0
Eucalyptus microcorys	134	15	13	65%	0.097 ± 0.026
Eucalyptus pilularis	40	10			0
Eucalyptus propinqua	52	9	2	10%	0.038 ± 0.027
Eucalyptus resinifera	20	6	1	5%	0.050 ± 0.049
Eucalyptus robusta	5	2	1	5%	0.200 ± 0.179
Eucalyptus saligna	7	2			0
Eucalyptus siderophloia	33	11			0
Eucalyptus tereticornis	1	1	1	5%	1.000
Lophostemon confertus	7	4			0
Melaleuca quinquenervia	6	1			0
Rainforest species.	3	1			0
Syncarpia glomulifera	46	11			0
Total	**445**	–	**20**		

Limitations of the field surveys

The field surveys for this study were based primarily on the presence and absence of koala scats (faecal pellets) beneath trees. This technique of sampling larger, regional areas based on the indirect signs of an animal's presence is now a well-accepted and resource-efficient survey method for cryptic, difficult to detect species. Koalas are arboreal species and can be difficult to detect and often go unnoticed. Koala scats, however, are reasonably distinctive and can be detected beneath the trees they have occupied more readily than the koalas themselves. This indirect method facilitates surveys across large areas and varying landscapes and improves detection of the species.

There are factors, however, that can influence both the persistence of koala scats and the ability to locate them. Koala scats decay over time, with the rate of decay influenced by factors such as rainfall, humidity, temperature, location in the landscape and invertebrate activity (Cristescu *et al.* 2012). Studies of decay rates of scats, however, have shown that, on average, scats decay slowly enough to ensure a low rate of error due to false negatives (Rhodes *et al.* 2011). The detection of scats can also be influenced by the complexity of the ground cover and litter depth; searching can be more difficult in locations with dense ground cover of species, such as the weed Lantana (*Lantana camara*) or in wetter areas where native sedges and reeds occur. For example, Cristescu *et al.* (2012) found that wetlands had the worst levels of detectability owing to the dense cover of ground vegetation and the most rapid rates of decay, whereas other vegetation types in drier locations and with a simpler layer of litter had five times better detectability.

The differences in detectability between habitats, combined with potential decay of scats over time, could thus influence survey results and potentially result in an underestimates of koala activity or numbers, and thus underestimates of the importance of what could actually be significant koala habitat, or result in a false negative for presence at a location (Rhodes *et al.* 2011; Cristescu *et al.* 2012).

During the period of this study (October 2014 to March 2015) rainfall for the area varied from below average for October 2014 to more than double the average in February 2015, with a number of rain and storm events where the intensity of rainfall was locally high occurred in some months (see Table 5). . It is possible that decay rates of scats may have been influenced by the increased exposure to rain and surface water and more humid microclimates (Cristescu *et al.* 2012). If linked with the difficulty of detectability in some locations, the potential for a false negative (no scats detected but koalas may actually be present) is possible at some of the survey sites.

Further, owing to lack of access where landholders withheld permission to enter properties or, in some cases, lack of close vehicle access, a number of areas were not sampled.

The combined influence of these factors on overall results in this study is likely to be low given the systematic nature of the survey methodology but needs to be considered and that the lack of scats at some sites may not be a true indication of actual absence of koalas at those sites.

Table 5 Rainfall statistics for Nambucca township for the study period October 2014 – March 2015 (Source: Bureau of Meteorology, http://www.bom.gov.au/).

Month and year	Highest daily rainfall (mm)	Total rainfall for month (mm)	Long-term average for month (mm)
Oct 2014	6	12	96
Nov 2014	53	119	104
Dec 2014	70	245	137
Jan 2015	76	225	169
Feb 2015	104	494	207
Mar 2015	159	243	232

4 Mapping of koala habitat

As part of this study, koala habitat was mapped for the koala study area using the vegetation mapping of the Nambucca LGA undertaken by the NSW Office of Environment and Heritage (OEH 2015) as a base layer. This has provided a koala habitat map delineating three classes of koala habitat for use by Council in determining and assessing areas of likely koala habitat and usage.

4.1 Koala habitat mapping methodology

The vegetation of the Nambucca koala study area has been mapped in detail by the OEH Regional Operations Group Coffs Harbour (OEH 2015). For the analysis and mapping of koala habitat, mapped Nambucca vegetation community types were ranked into Primary, Secondary (Class A), Secondary (Class B) and Non-koala habitat based in part on the criteria listed in the NSW koala recovery plan (Appendix 3 in DECC 2008; see Table 6).

To determine whether koala habitat criteria were met, the relative abundance of feed tree canopy versus the total canopy was calculated. The canopy cover for each species was moderated by its frequency of occurrence in a plant community type. Frequency of occurrence and canopy cover scores for the various vegetation types were taken from the Vegetation Classification for the Northern Rivers Catchment Management Area of New South Wales (Appendix 9 in OEH 2012). Floristic data from the Nambucca vegetation mapping project (OEH 2015) and data collected during the koala surveys were used to refine this process.

This process identified all areas of preferred koala habitat irrespective of koala presence at any given time.

Table 6 Classification of koala habitat ranks based in part on the NSW koala recovery plan (Appendix 3 in DECC 2008).

Primary Habitat	Vegetation associations and/or communities in which primary food-tree species form ≥50% of the canopy
Secondary (Class A) Habitat	Vegetation associations and/or communities in which: primary food-tree species form 30–50% of the canopy or primary and secondary species combine to form ≥50% of the canopy
Secondary (Class B) Habitat	Vegetation associations and/or communities in which secondary food-tree species form ≥50% of the canopy

Core koala habitat

Core koala habitat, as defined by State Environmental Planning Policy No 44 – Koala Habitat Protection (SEPP 44), includes areas of land with a resident population of koalas as evidenced by attributes, such as breeding females, recent sightings and historical records. SEPP 44 further identifies potential koala habitat as areas of native vegetation in which trees of types listed in Schedule 2 of SEPP 44 constitute at least 15% of the total number of trees

in the upper or lower strata of the tree component. Two SEPP 44 Schedule 2 tree species occur within the mapping area: Tallowwood (*Eucalyptus microcorys*) and Forest Red Gum (*Eucalyptus tereticornis*). Core koala habitat within the study area was identified by intersecting potential koala habitat with field-survey sites with koala activity and survey records, and the results of the generational persistence mapping. This process identified areas of koala habitat where occupation for at least three generations or more could be shown.

4.2 Results of koala habitat mapping

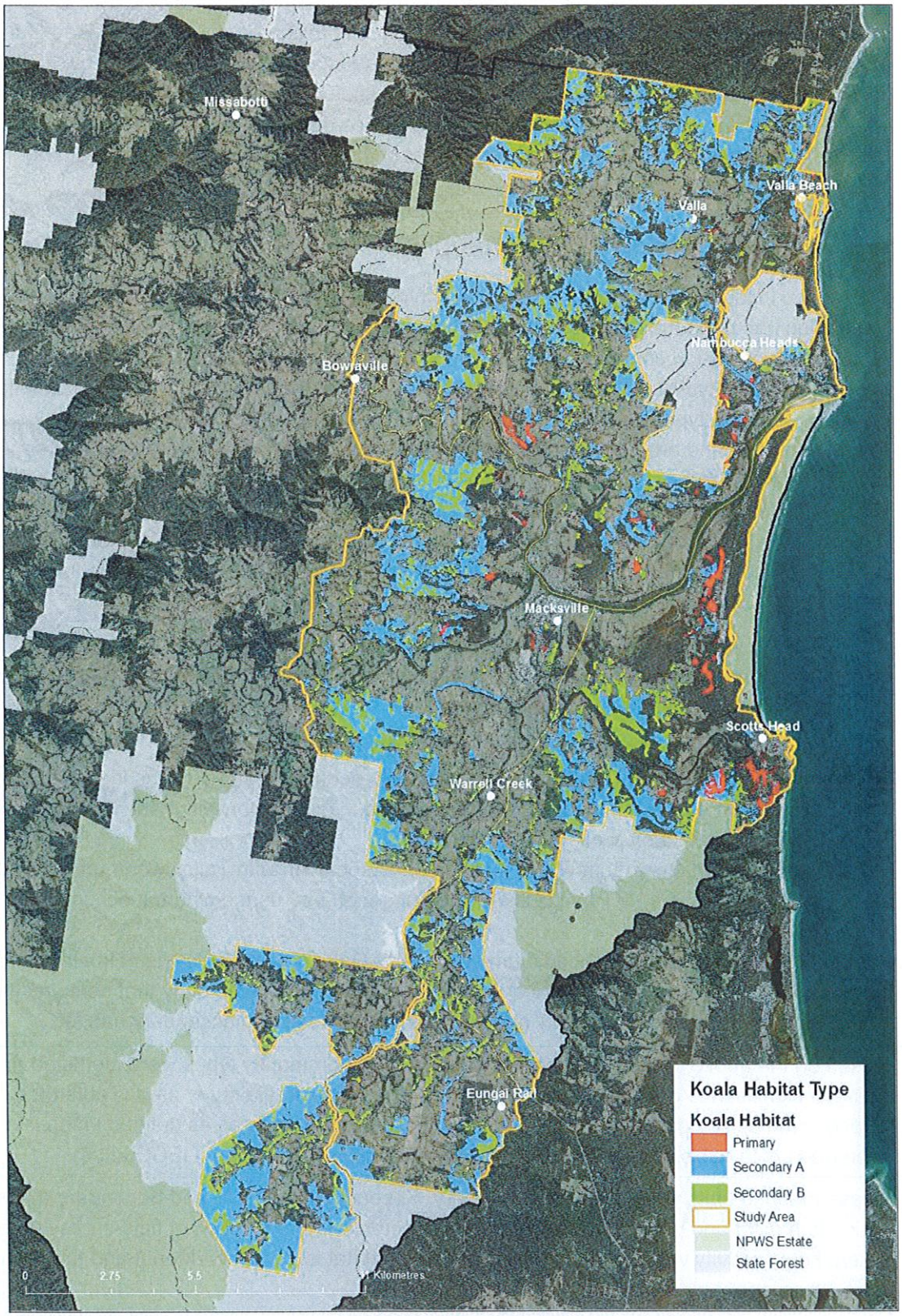
A total of 61 Nambucca vegetation community types, covering 13 565 ha of native vegetation has been mapped in the 36 301 ha in the Nambucca koala study area. The 61 Nambucca vegetation community types included 8 dry sclerophyll forest types, 9 wet sclerophyll forest types, 12 forested wetland types, 11 freshwater wetland types, 6 heathland types, 9 rainforest types and 5 saline wetland types. A total of 21 of the vegetation types are likely to contain, and are equivalent to, nine threatened ecological communities (TECs) under the NSW *TSC Act*, covering an area 2919 ha. There are also three TECs under the Commonwealth *EPBC Act* (one vulnerable, two critically endangered). An additional area of 3898 ha of extant vegetation was also mapped but not assigned to a vegetation community type, which included native remnants, rainforest and acacia pioneer, exotic and plantation vegetation (OEH 2015).

In accordance with the field survey results, analysis of tree-species strike rates for koala usage and information on regional koala habitat preference, the mapping and classification of koala habitat was based on the following criteria:

1. Tallowwood is recognised as a primary food tree (PFT)
2. Forest Red Gum and Swamp Mahogany are recognised as PFTs (as identified by surveys in neighbouring LGAs) but are limited in distribution within the Nambucca koala habitat study area
3. Small-fruited Grey Gum where it occurs in association with Tallowwood on better nutrient soils is a PFT and is likely to be of secondary usage where it occurs elsewhere
4. Sydney Blue Gum, Flooded Gum and Forest Oak show lower levels of koala use where they occur adjacent to or as part of a vegetation community that contains the primary food trees listed in 1 and 2 above; these comprise secondary habitat

Based on the above criteria, 13 Nambucca vegetation community types were identified as being of significance as habitat for koalas in the Nambucca koala study area (Table 8). These communities contain primary and secondary koala food trees as defined in the preferred koala habitat classification in the NSW koala recovery plan (DECC 2008).

These mapped units were ranked into Primary, Secondary (Class A) and Secondary (Class B) koala habitat and verified against historical records and the location of field-survey sites where koala activity was recorded. Mapped koala habitat is shown on Map 8 and the areas for each category are summarised in Tables 7 and 8.



Map 8 Mapping of koala habitat types (Primary, Secondary (Class A) and Secondary (Class B)) across the koala habitat study area.

Table 7 Area of mapped koala habitat classes in each precinct and proportion (%) of total area of mapped koala habitat.

Preferred koala habitat class	Precinct	Area (ha)	% of total area of koala habitat
Primary Habitat	1	80	0.9
	2	5	0.1
	3	129	1.4
Secondary (Class A) Habitat	1	3162	35.2
	2	2239	24.9
	3	1035	11.5
Secondary (Class B) Habitat	1	1047	11.6
	2	708	7.9
	3	586	6.5
Total area		**8991**	**100**

Core koala habitat

All areas mapped as core koala habitat are contained within Precinct 1 and comprise an area of 1600 ha (Map 9). The area contains 251 mapped vegetation polygons that range in size from 0.25 ha to 107.6 ha. Areas of mapped preferred koala habitat where generational persistence was not demonstrated by at least three koala generations may in fact comprise core koala habitat, but there are currently insufficient data (actual site survey evidence) to show that these areas are currently occupied. It is likely that additional core koala habitat exists in Precinct 2 in the south-west of the study area, but these areas require additional surveys to confirm individual locations.

Feed-tree preference

The results of this study correspond to results of other studies of koala food-tree preferences on the north coast of NSW (Appendix 3 of the NSW State Koala Recovery Plan – DECC 2008; Coffs Harbour LGA – Lunney *et al.* 1999; eastern Kempsey Shire LGA – Biolink 2011; Tweed LGA coastal area – Phillips *et al.* 2011; Byron Shire LGA coastal area – Phillips and Hopkins 2012; south-eastern Lismore – Lismore City Council 2013; Ballina Shire LGA – Biolink 2013a; and Port Macquarie-Hastings LGA – Biolink 2013b).

The list of primary and secondary food trees in Table 9 is also consistent with the results of other studies undertaken in the adjoining Bellingen LGA (OEH 2014a) and to the north in Pine Creek State Forest (Smith and Andrews 1997), the Pine Creek State Forest Koala Plan of Management (State Forests of NSW 2000) and for the Pacific Highway upgrade at South Bonville (AMBS 2012) and Warrell Creek to Nambucca (GeoLink 2013, 2014). The study in Pine Creek State Forest (Smith and Andrews 1997) reported that Tallowwood and Small-

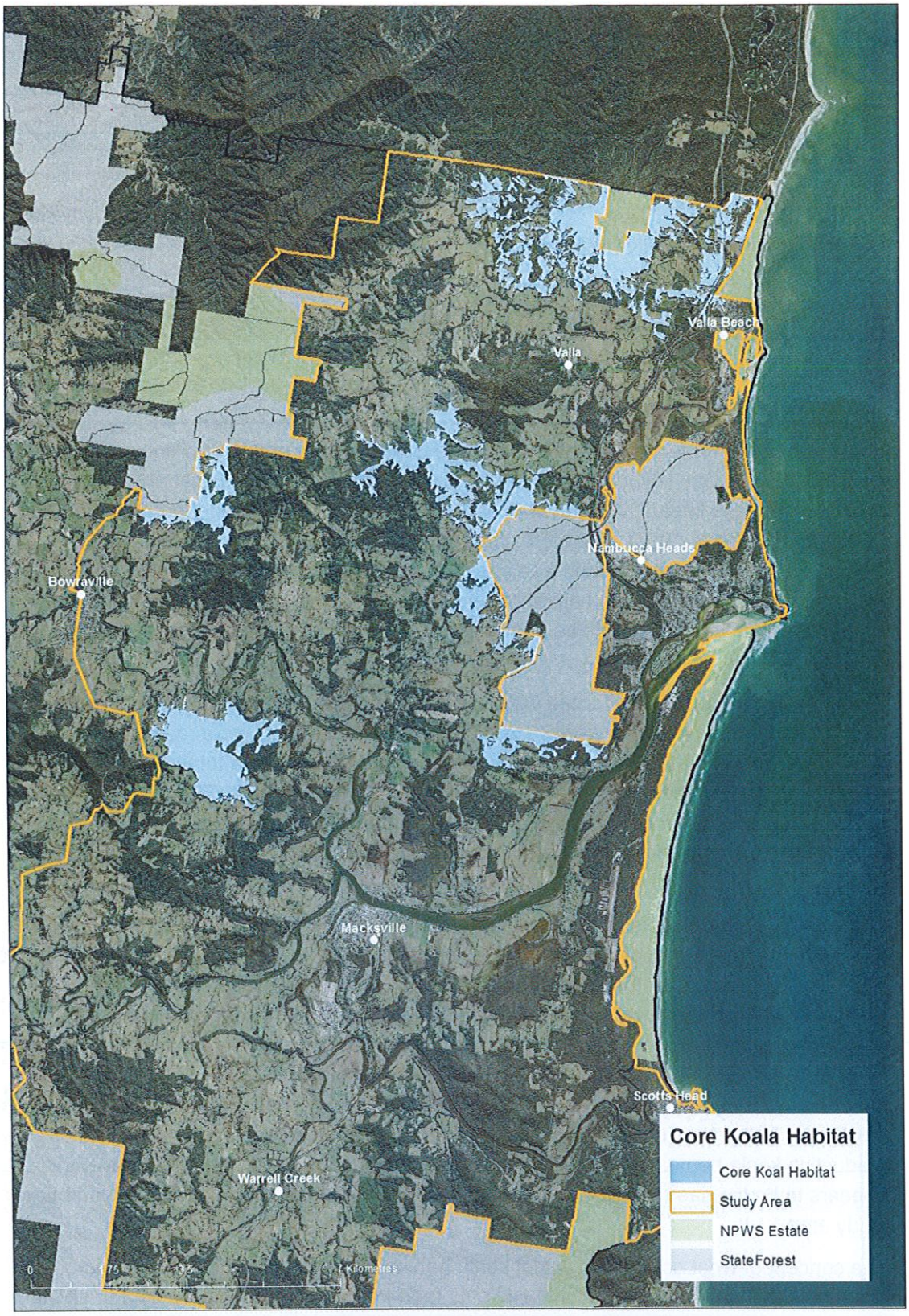
fruited Grey Gum were preferred species in both frequency and volume of intake with Forest Red Gum, Sydney Blue Gum and Swamp Mahogany also utilised.

Table 8 Koala habitat categories and mapping areas.

Nambucca vegetation community type (Nambucca code)	Areas of preferred koala habitat class (ha)			
	Primary	Secondary (Class A)	Secondary (Class B)	Total
Brush Box – Tallowwood – Sydney Blue Gum shrubby wet open forest of coastal hills and escarpment ranges (NAM_WSF02)		520		520
Precinct 1		108		108
Precinct 2		267		267
Precinct 3		145		145
Flooded Gum moist open forest of sheltered lower slopes and gullies			904	904
Precinct 1			385	385
Precinct 2			341	341
Precinct 3			178	178
Forest Red Gum – Pink Bloodwood – Grey Ironbark open forest to woodland near coastal hills (NAM_DOF05)	41			41
Precinct 1	2			
Precinct 3	39			
Spotted Gum – Small-fruited Grey Gum tall open forest with dense Brown Myrtle mid-story on coastal foothills (NAM_WSF06)		17		17
Precinct 1		17		
Spotted Gum – Tallowwood – Thick-leaved Mahogany – Small-fruited Grey Gum – Grey Ironbark grassy open forest on shallow sedimentary soils (NAM_DOF12)		483		483
Precinct 1		14		
Precinct 2		469		
Spotted Gum – Tallowwood – Thick-leaved Mahogany – Small-fruited Grey Gum – Grey Ironbark wet shrubby open forest on sheltered slopes (NAM_WSF09)		115		115
Precinct 1		33		
Precinct 2		82		

Nambucca vegetation community type (Nambucca code)	Areas of preferred koala habitat class (ha)			
	Primary	Secondary (Class A)	Secondary (Class B)	Total
Swamp Mahogany – *Melaleuca sieberi* shrub/sedge swamp forest on low lying sandy areas (NAM_ForW12)	2			2
Precinct 3	2			
Swamp Mahogany – tea-tree – Tassell Rush forested wetland of waterlogged wallum soils (NAM_ForW13)	69			69
Precinct 1	2			
Precinct 3	67			
Swamp Mahogany – Willow Bottlebrush – Broad-leaved Paperbark forested wetland (NAM_ForW08)	101			101
Precinct 1	76			
Precinct 2	5			
Precinct 3	20			
Tallowwood – Blackbutt moist shrubby tall open forest of the hinterland ranges (NAM_WSF07)		2165		2165
Precinct 1		1331		
Precinct 2		178		
Precinct 3		656		
Tallowwood – Small-fruited Grey Gum – Ironbark – Forest Oak dry sclerophyll forest (NAM_DOF11)		536		536
Precinct 1		246		
Precinct 2		134		
Precinct 3		157		
Tallowwood – Small-fruited Grey Gum – Ironbark – Forest Oak wet sclerophyll forest (NAM_WSF05)		2600		2600
Precinct 1		1412		
Precinct 2		1110		
Precinct 3		78		
Turpentine – Brush Box – Flooded Gum – Blackbutt shrubby moist forest of sub-coastal lowlands (NAM_WSF04)			1438	1438
Precinct 1			663	
Precinct 2			368	
Precinct 3			407	

Nambucca vegetation community type (Nambucca code)	Areas of preferred koala habitat class (ha)			
	Primary	Secondary (Class A)	Secondary (Class B)	Total
Total (ha)	213	6436	2342	8991



Map 9 **Core koala habitat within the koala habitat study area.**

Table 9 Primary and secondary koala food trees in the Nambucca koala study area.

Primary food trees	
Tallowwood (*Eucalyptus microcorys*)	*Note that Tallowwood and Small-fruited Grey Gum are common and widespread across the study area on different soil substrates whereas Forest Red Gum and Swamp Mahogany have a limited distribution in swamp and riparian areas or primarily near the coast*
Small-fruited Grey Gum (*Eucalyptus propinqua*)	
Forest Red Gum (*Eucalyptus tereticornis*)	
Swamp Mahogany (*Eucalyptus robusta*)	
Secondary food trees	
Flooded Gum (*Eucalyptus grandis*)	
Sydney Blue Gum (*Eucalyptus saligna*)	

Analysis of scats for leaf fragments within Pine Creek State Forests also showed that, where available, Forest Oak (*Allocasuarina torulosa*) was eaten and overall scat abundance was shown to increase linearly with the abundance of Forest Oak within the forest community (Smith and Andrews 1997). Therefore, where Forest Oak occurs in association with Tallowwood or other primary food tree species at any site it should be considered an important component of koala habitat composition. Similarly, Turpentine *(Syncarpia glomulifera*) has been shown to be important to koalas for resting and shelter during severe weather.

During koala monitoring associated with the upgrade of the Pacific Highway between South Bonville and northern Raleigh (AMBS 2012), 34 individual koalas were radiotracked for a cumulative total of 12 452 days (mean of 366 days per koala) and a total of 1986 observations were made of koalas using 39 different species of tree. The study found that koalas were recorded most often in Tallowwood, Flooded Gum and Small-fruited Grey Gum (AMBS 2012). This work also recorded koala usage of Turpentine, most likely as a shelter species.

Analysis of larger datasets relating to koala use of food trees (Biolink 2011; Phillips *et al.* 2011) indicate that although Tallowwood is considered a primary food tree for koalas where it occurs on alluvial and other deposited soil landscapes, use of Tallowwood can be significantly lower on low-nutrient erosional and residual soil landscapes. Thus, koala carrying capacity (habitat quality) can be markedly lower on lower nutrient soil landscapes even with the presence of identified primary food trees, such as Tallowwood and Small-fruited Grey Gum. In these circumstance available leaf nutrients, moisture content and toxin levels may become a limiting factor to koala carrying capacity and result in larger, less productive koala home-ranges and lower overall abundance. Although speculative, this appears to be the case in many parts of southern and south-western areas the Nambucca study area.

The concept of what constitutes actual koala habitat therefore needs to be taken into account both in protecting the identified koala feed trees and a range of resting or shelter trees across the landscape to provide for the overall well-being and sustainability of the population. In effect, this may mean that areas of suitable habitat could be unoccupied at any one point in time as koalas move between the different environs and landscape features within their home-range.

Management precincts

In order to facilitate discussion of the results and to provide for more localised management of koalas the Nambucca koala study area has been divided into three precincts that reflect variances in the findings throughout the Nambucca LGA (Map 11).

Precinct 1

The records analysis showed that Precinct 1 contained the highest number of historical and recent koala records. The field surveys also showed that Precinct 1 contained the highest number of active sites and the highest activity levels. The generational persistence analysis supports the results of the koala habitat surveys and records analysis. The generational persistence analysis shows a cluster of cells in the precinct where koalas have persisted for at least the last 3–4 generations (18–24 years). The results highlighted the persistence of a koala population within and adjoining Nambucca State Forest and an important koala population west of the study area in the state forests and national parks that form part of the Great Eastern Ranges. A significant outcome of the study is the confirmation of an important koala population in the area around Picket Hill – and west of Valla to the coast and south to the township of Valla.

The map koala activity at survey sites (Map 6) verifies the findings of the analysis of koala records and field surveys in identifying major population activity cells in the north and north-east of the koala study area. This finding, together with the generational persistence mapping (Map 4) identifies the long-term presence of a koala population in this area.

The records analysis shows an absence of continuous koala records in the last three koala generations in the areas to the south-west of Picket Hill and the Newry Creek area. This result needs further research to determine occupation levels in this area. Landholder comments during the field surveys confirm the above results, with many landholders not having seen koalas in the areas south-west of Picket Hill for at least 10 years.

All areas of identified core koala habitat as defined under SEPP 44 are contained within Precinct 1.

Precinct 2

The persistence of a widespread but low-density koala population in Precinct 2, in State Forest and National Park Estate as well as on private land between Macksville and Bowraville and south of the Nambucca River (refer Map 11) is supported by the records analysis and the field surveys.

Locations showing generational persistence of koalas generally correspond with the results of the koala habitat surveys but there are areas in the south-west of the precinct (e.g. west of Eungai Rail) where koalas were recorded during the surveys but historical records are absent. Koalas are likely to have persisted in these areas for some time and this result highlights the inconsistency of historical reporting of koalas across the study area and why the location and dates of koala records should be interpreted in the context of other survey results.

The persistence of a koala population (three cells) in the western part of the Nambucca LGA, mainly in State Forest and National Park Estate south-west of Warrell Creek (Map 4) is supported by the field surveys. It is likely that core koala habitat exists in this area, although this needs further investigation.

A number of landholders in the western parts of this precinct commented during the field surveys that they not seen koalas for at least 10–15 years. Further work is required to monitor the population in this area, including encouraging landholders to report any records of koalas.

Precinct 3

All available evidence gathered in Precinct 3 leads to the conclusion that koalas are absent or in extremely low numbers across these coastal areas even though suitable habitat is present. Should a remnant population exist in this precinct, direct management would be essential to ensure its long-term viability.

Koalas were historically reported in this area. One long-term resident noted seeing and hearing animals in the 1960s but not since (Charlie Barber, personal communication). Two more recent records were reported during a community survey in 1996 but these sightings have not been confirmed and a number of field surveys in the area have not recorded koalas.

Further research and monitoring is required to determine fully the importance of areas of mapped koala habitat in Precinct 3, including encouraging landholders to report any koala records.

4.3 Discussion

There has been a long history of clearing for agriculture and habitat disturbance resulting from forestry activities, weed invasion and fire throughout the Nambucca koala habitat study area. These human activities have significantly altered the availability and quality of suitable habitat for koalas and consequently the distribution and abundance of koalas. This study has looked at a range of datasets in order to determine contemporary koala distribution and habitat use within the study area and to identify areas of important koala habitat.

The generational persistence analysis highlights the difference in historical records and koala occupation between the north and north-east of the study area and areas south of the Nambucca River. Although there are numerous records in the north, the analysis indicates that despite being widespread south of the Nambucca River, reporting rates of koalas in this area is low. In the area east of Macksville, including lands west of Scotts Head, koalas are now absent or in extremely low numbers.

The overall results of the analysis of historical koala records, field surveys, generational persistence analysis and the vegetation mapping were found to be supportive in identifying areas of importance to koalas. This is particularly so where areas of higher numbers of koala records, sustained generational persistence and suitable habitat with recent koala records overlap.

The outcome of the various assessments undertaken supports the anecdotal evidence that koalas have a long history of occupation in many parts of the koala habitat study area. However, as mentioned above in the introduction, the settlement, logging and clearing of the most productive and fertile lands has had a significant impact on what would have been the highest quality koala habitat. Large areas of the original forest were cleared for agriculture and forestry before 1940 and, although large areas remain cleared, regrowth forests have established in some areas. The young age of many forested areas is demonstrated by the size-classes of the 3295 trees sampled during the field surveys. Most eucalypt trees

averaged between 30 and 45 cm in diameter at breast height (dbh) with a mean diameter of all trees being only 29 cm. Although many of these regrowth forests now support koalas, there is an absence of records in some areas either as a result of ongoing threats (such as wildfire, road-strike) or because the forest remnants are isolated and animals have not been able to re-establish. In particular, areas east of the existing Pacific Highway and south of the Nambucca River, which once supported koalas historically now appear to be unoccupied.

5 Threats to koalas

Koalas are exposed to a number of threats, including loss and disturbance of habitat, diseases such as *Chlamydia*, road-strike by vehicles, attack by dogs, fire and severe weather conditions. Records of koala admittances to WIRES and other carer groups, such as the Friends of the Koala (Lismore) and the Koala Hospital (Port Macquarie) show that in many areas these threats can have significant effects on local koala populations. For example, in the Lismore area for the 12 months starting in January 2010, 306 koalas were admitted with 220 mortalities, including 131 suffering from diseases, 32 road-strike, 17 dog attacks and 40 classed as other causes.

5.1 Koala threat analysis

An assessment of the threats to koalas was undertaken based on records of koalas taken into care by WIRES in the Coffs Harbour region (NSW Wildlife Information, Rescue and Education Service Inc.; see http://www.wires.org.au/) and by assessing records of road-killed koala for the major roads within the koala study area.

WIRES records of koalas for the Coffs Harbour region were collated by Chris Moon as part of a project to review koala population trends in the Coffs Harbour LGA following approval of their Comprehensive Koala Plan of Management (Lunney *et al.* 1999) in 2000. For the Coffs Harbour LGA, Bellingen LGA and the Nambucca LGA, a total of 613 cases were reported to WIRES between July 2005 and March 2013. A breakdown of these records is given in Table 10 below.

Table 10 Number of koalas reported to WIRES for the wider Coffs Harbour region (Coffs Harbour, Bellingen and Nambucca LGAs), July 2005 – March 2013. Key threats comprise 290 records (48.1% of total reports below).

Reason for report	Number of animals reported	Proportion of total for key threats
Key threats		
Road strike	104	35.9%
Sick or other health issue	171	59.0%
Dog attack	15	5.1%
Subtotal	**290**	**100**
Other threats		
In unsafe place	230	
Other	93	
Overall total	**613**	

Table 11 shows those records for the Nambucca LGA only, in which there were only 10 reports to WIRES.

Table 11 Breakdown of causes of Koala reports to WIRES for the Nambucca LGA, July 2005 – March 2013.

Road-strike	Sick or other health issue	Dog attack	In unsafe place	Enquiry only	Other	Total
1	1	0	1	4	3	10

Although records for the wider Coffs Harbour area, including Coffs, Harbour, Bellingen and Nambucca LGAs, indicate that koala health issues are significantly higher than any other reported threats, overall numbers of koalas reported to WIRES for only the Nambucca LGA are extremely low. This low number of reports makes it difficult to determine which impacts are most significant in the Nambucca LGA. It is also worth noting that dog attacks and car-strike are often under reported as the carcass or injured animal is often not found.

Only one koala road fatality was reported to WIRES for the Nambucca LGA. However five koala fatalities were recorded between 1992 and 2014 on the Pacific Highway in the southern section of the Bellingen LGA to the immediate north of the study area. WIRES have advised that there have been no recent reports of koala injury or fatality for the Nambucca LGA (Helen Jervis, personal communication, May 2015).

5.2 Threatening processes

Habitat loss, fragmentation and barriers to movement

As discussed previously in this report, clearing of forests in the Nambucca region began in the 1840s and continued well into the 1900s. As a result, most of the productive land on better nutrient soils was cleared for agriculture, including dairying, and many of the remaining areas of forest have been subject to forestry, fire, invasion by weeds, or combinations of these factors. This pattern of historical land-use is similar to that of much of eastern Australian, where agriculture, forestry and population pressure have had an impact on biodiversity values.

Historical clearing of the most fertile landscapes is likely to have significantly affected the distribution and abundance of koalas. The loss and isolation of habitat over many decades would have significantly reduced the abundance and distribution of koalas, confining animals to the remaining patches of vegetation on private lands and to the larger areas of forest on public lands. This study has found little or no re-establishment of koalas in some areas of regrowth forest, with koalas now in very low numbers or absent from some larger areas of forest which contain otherwise suitable habitat.

Additionally, the influence of isolation of patches of habitat and size of remnant patches can affect the ability of koalas to survive a range of threats, particularly where the chance for immigration or recolonising is low. Thus the impacts of fire, forestry, predation or attacks by dogs, road-strike, disease and invasion of habitat by weeds can lead to localised extinction in smaller remnants with little chance for subsequent recruitment.

Major roads, such as the Pacific Highway, larger rivers, expanses of cleared land and areas of unsuitable habitat (rainforest, heathland, wetlands) can form a significant barrier to the movement and dispersal of koalas.

Maintaining and rebuilding appropriate corridors and linkages is vitally important in providing the habitat connectivity needed to allow koalas to move through the landscape and to manage changing threats, ecological and climatic variability and genetic diversity. Maintenance of adequate landscape connectivity across the koala study area is important to enable north–south and east–west movement of koalas (and other fauna) and to maintain population viability, particularly in the northern coastal area (Map 10).

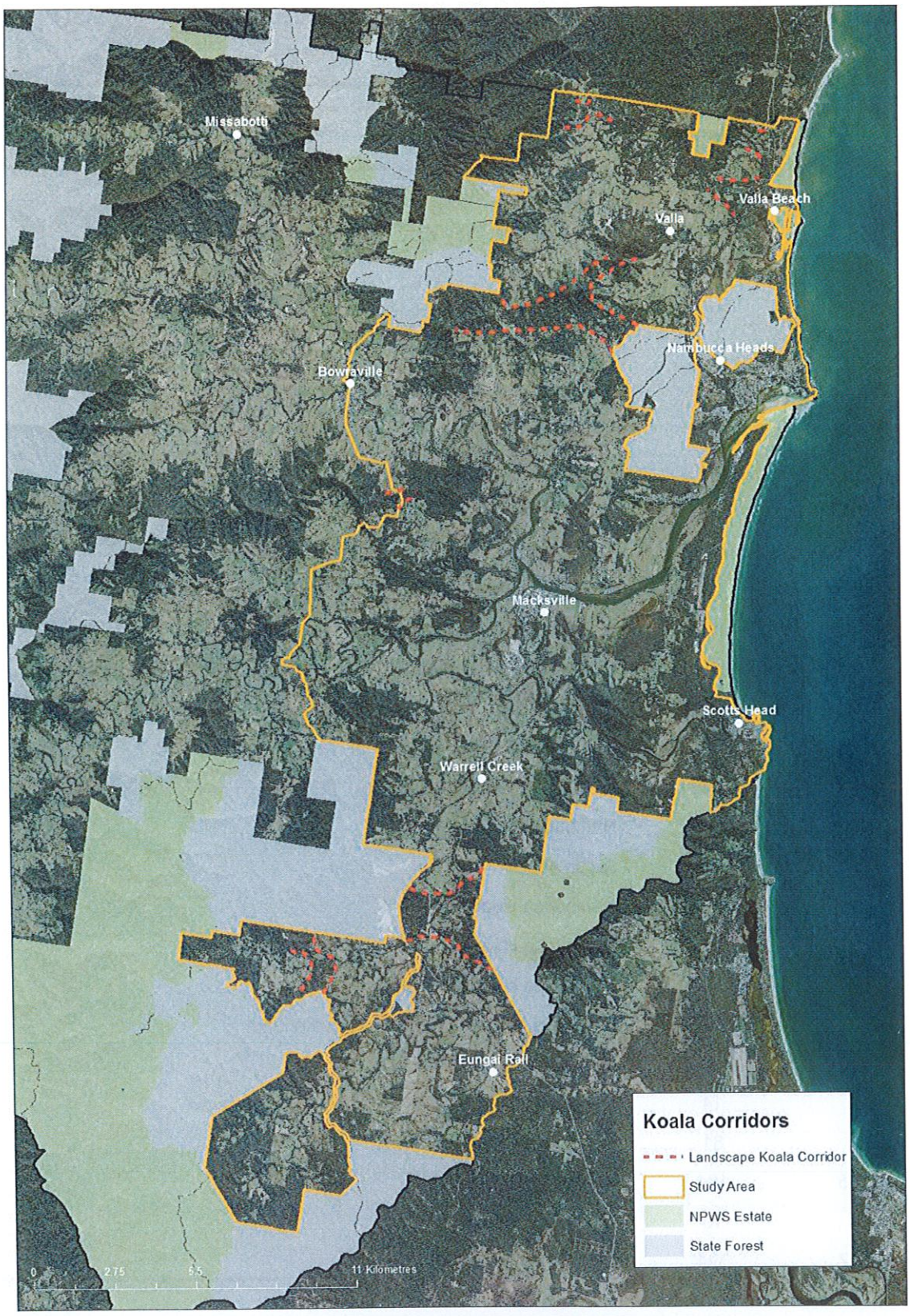
Wildfire

Wildfire is an integral component of the Australian bushland and periodic wildfires have occurred in large areas of the Nambucca LGA. Wildfires, however, particularly high-intensity canopy fires, have the potential to severely affect koala populations, either through the direct impacts of flames, heat and smoke inhalation and indirectly through the loss of food resources.

Where populations are small or patches of habitat are small and isolated, wildfire can lead to combinations of population crashes, localised extinction or impeded recovery of populations. In such areas, the absence of wildfire for at least three koala generations (minimum 18 years) is crucial for population recovery, but additional recruitment to the population may be needed and so fire management cannot be considered in isolation of other impacts and habitat factors such as connectivity.

Although not conclusively demonstrated, wildfire may have played a role in the decline of koalas in the Nambucca koala study area and may have influenced the distribution of koalas in drier forest types. Map 11 shows the areas and dates of recorded wildfire in the Nambucca LGA. The areas mapped are primarily on public lands where there are better records of fire history and may not fully represent all wildfires that have occurred on private land. The recording of wildfires, even on public land, was not done systematically until the late 1900s and it is likely that a number of additional wildfires have occurred. Table 12 summarises the distribution and years of known and mapped wildfires. There have been no large wildfires since 2003 although a fire occurred in Nambucca Heads State Forests in 2007, burning an area of 394 ha.

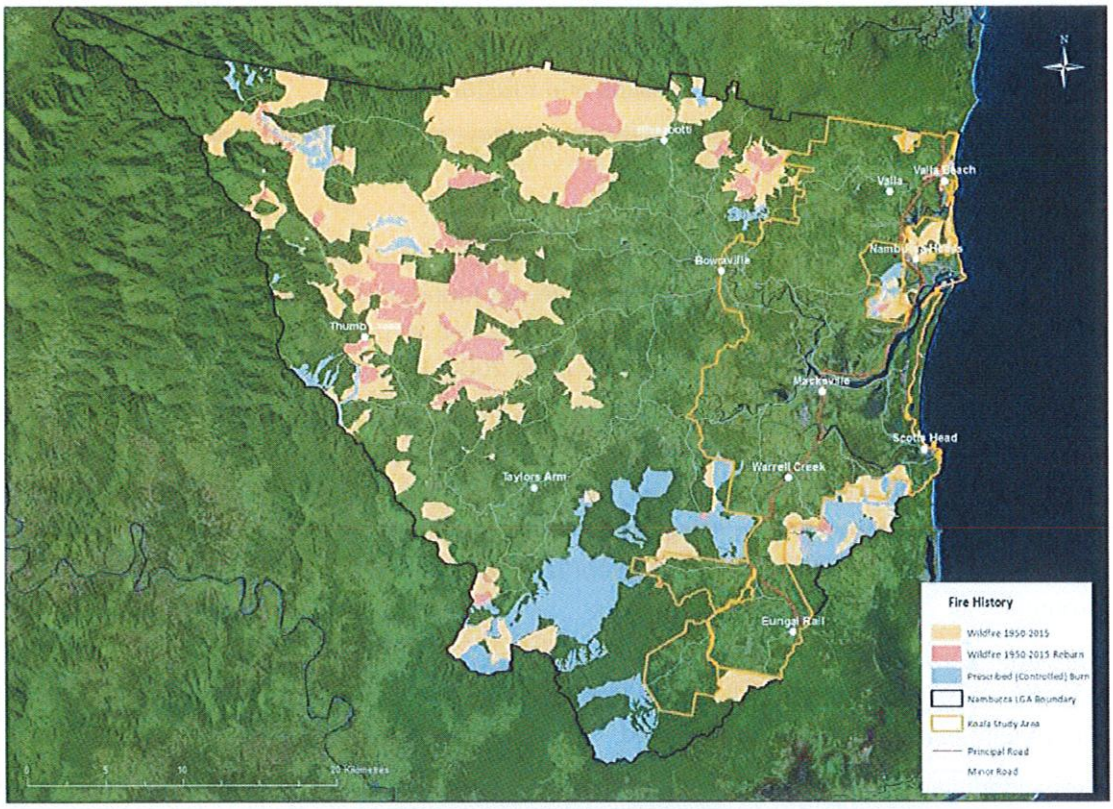
Prescribed burns in areas of koala habitat also have the potential to affect koalas. Where prescribed burning is undertaken in koala habitat it should be of very low intensity, with flame heights below 2 metres, and should avoid trees occupied by individual animals where possible.



Map 10 **Landscape koala corridors across the koala study area.**

Table 12 Summary of wildfires in or adjacent to Nambucca LGA NP, National Park; NR, Nature Reserve; SF, State Forest.

Year	Area burnt (ha)	Location
1926	2182	Yarriabini NP, Way Way SF, private land
1949	1468	Yarriabini NP, Way Way SF, private land
1953	993	Yarriabini NP
1980	508	Way Way SF, private land
1981	84	Jagun NR, private land
	177	Nunguu Nirral Aboriginal Area, private land
1984	83	Jagun NR
	84	Jagun NR, private land
1990	120	Private land
1991	3433	Tamban SF
1993	27	Bollanolla NR, private land
	170	Bollanolla NR, private land
	84	Ingalba SF, private land
1994	38	Jagun NR
1995	70	Ngambaa NR, private land
1997	2822	Way Way SF, private land
2000	254	Nambucca Heads SF East
2001	38	Jagun NR
	160	Nambucca Heads SF East
	61	Nambucca Heads SF West
2002	86	Nambucca Heads SF West
2003	1065	Bollanolla NR, Viewmont SF, private land
	5	Nambucca Heads SF East
	14	Nambucca Heads SF West
	81	Nambucca Heads SF West
2005	164	Ingalba SF, private land
	19	Nambucca Heads SF East
2007	394	Nambucca Heads SF West



Map 11 Fire history within the Nambucca LGA.

Road-strike and road-kills

Death or injury of koalas from vehicle strikes can be a significant factor contributing to declines in abundance and distribution of koalas in areas where roads with moderate to high traffic volumes traverse koala habitat. Road strike is typically seasonal and usually peaks in the spring and summer breeding season, from August to February. Mortality is also linked to roads with high traffic volumes, high speed limits (>50 kph) and where there is poor roadside visibility and lighting.

Only one koala fatality has been recorded by WIRES along the Pacific Highway within the koala study area. There are five other records of road-killed koalas north of the koala study area in the Bellingen LGA including one killed in October 2014 on the Pacific Highway north of Ballards Road (J. Turbill, personal communication). However, further to the north a much higher road mortality was recorded before and during the Pacific Highway upgrade between Raleigh and Bonville in the Bellingen and Coffs Harbour LGAs (AMBS 2012). In this section of highway there were 65 reported koala mortalities between 2000 and 2010. The highest for an individual year was 13 in 2000 and lowest was 0 in 2010 (as fauna fencing had been installed by that time). As reported elsewhere on the north coast, road-strike peaked during the breeding season, from August to November (AMBS 2012).

Fauna fencing, underpasses and overpasses are being constructed as part of the Pacific Highway upgrade through the Nambucca LGA and these mitigation measures may help reduce future koala fatalities. However, koalas do gain access to highways by moving around fences or down access roads and ramps. On the far north coast of NSW, between

Byron Bay and Chinderah, surveys indicated that of 28 koalas that were killed on the road since the opening of various section of the highway and 2014, 13 koalas were killed after gaining access via access ramps (Phillips and Fitzgerald 2014).

No other koala fatalities have been reported for other roads in the study area.

Dog attacks

Both domestic and wild dogs can cause koala fatalities. The impact of dog attack is often under reported as evidence of fatalities is often not found, but during research in which koalas are radiotracked, dog attacks are often reported as one of the most significant mortality factors (Dique *et al.* 2003; Lunney *et al.* 2004; Cristescu *et al.* 2011).

Fatalities from dog attacks are most prevalent where habitat is fragmented and koalas have to spend more time on the ground travelling between trees. Areas of greatest risk are those where urban and rural residential subdivisions adjoin or are interlinked with koala habitat and koalas are more likely to move through backyards. Dog attacks usually peak during the koala breeding season, from August to February, when koalas are more likely to be moving around.

Although there are no WIRES records of dog attacks within the Nambucca LGA, it is likely that the incidence of dog attack goes unreported as attacks usually occur in bushland areas where carcasses are not normally found.

Areas identified during this study where domestic dog attack may be a concern are the rural residential areas of Valla and Picket Hill, the urban areas around Valla Beach, and the rural areas west or Eungai Rail and north-east of Bowraville. Koalas scats were found in these areas during field surveys and a number of sightings of koalas have been reported.

The management of domestic dogs is regulated by the *Companion Animals Act 1998* under which dogs in public places must be under the control of a competent person and must not be allowed to roam or attack other animals. A significant part of enforcing the Act is public education and awareness of the impacts of dogs on koalas.

Disease

Disease in koalas is the major cause of koalas being taken into care and is reflected in WIRES records for the Coffs Harbour region, which includes Nambucca (Table 10). Disease can be elevated in populations in areas where koalas are suffering harassment or continued stress. Elevated levels of chlamydiosis in a koala population can severely compromise the health and breeding potential of females. Both chlamydia and the koala retrovirus (KorV) are known from north coast koala populations, including those in the Nambucca LGA, and it is likely that mortality from these diseases is widespread and often unreported.

Sick or injured animals, which often show the clinical signs of chlamydia infection, including a dirty wet bottom or infected eyes, should be reported to WIRES to allow for appropriate assessment and treatment.

Climate change

The potential effects of climate change on koalas and their habitat is yet to be fully determined. Research is suggesting that the effects of increased temperatures and CO_2 levels may influence a number of variables and which, in turn, may prove problematic for koalas. These changes include an increase not only in extreme hot days and temperature

but the number of these days occurring in the one event. Additionally, such events and the likelihood of extreme weather conditions, such as storms or drought, may directly affect individual koalas and, in the case of drought, increase potential for high-intensity wildfires.

Increases in the number of extreme hot days and the occurrence of consecutive extreme hot days are expected to increase on the north coast and may pose a significant risk to koala populations which are unable to seek refuge from the high temperatures or maintain sufficient water intake. An extended dry period before an extreme heat event may further deplete moisture stocks in koala feed trees, and compound the impact of high temperatures.

Increased CO_2 levels in the atmosphere (from 280 ppm to 387 ppm or higher since the Industrial Revolution) may result in faster plant growth but at the same time also change nutrient levels (less protein) and increase the tannin level of eucalypt leaves. As CO_2 levels increase, eucalypt leaves are likely to become less suitable to koalas (IUCN 2009). Adaption by koalas to lower quality food may be problematic as they cannot simply eat more leaves and may need to be more selective in choice of trees and individual leaves. This may result in koalas spending more time on the ground looking for suitable trees and therefore more prone to other threats.

6 Considerations under the *Environment Protection and Biodiversity Conservation Act 1999*

The koala is listed as a vulnerable species in NSW under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (*EBPC Act*). Under the *EPBC Act*, proponents undertaking a proposed activity that has the potential to affect an important population must assess whether the proposal needs to be referred to the Australian Government Department of Environment. The 'EPBC Act Referral Guidelines for the Vulnerable Koala' (Department of Environment 2014) focusses on assessing impacts on 'habitat critical to the survival of the species' and impacts that 'substantially interfere with the recovery of the species'.

Habitat is considered critical to the survival of the koala if the area of impact scores five or more using the Referral Guidelines for the Vulnerable Koala habitat assessment tool. The assessment tool considers the presence of koala records, vegetation composition, habitat connectivity, key existing threats and recovery value.

The results of the field surveys conducted as part of this study indicate that parts of the study area, particularly in precinct 1, may meet the definition of 'habitat critical to the survival of the koala.' This includes, but is not limited to, vegetation communities within the study area that have been identified as core koala habitat (Map 9). Additional areas that have not been mapped as core koala habitat may also meet the definition of 'habitat critical to the survival of the species' under the *EPBC Act* and should be assessed using the habitat assessment tool.

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