# Redlands Coast Koala Population and Habitat Assessment

## Final Report to Redlands City Council

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**Cover Photo:** A North Stradbroke Is. koala; individuals from NSI are notable for extensive white coloration on lower half of body. Photo by Grant Brearley.

## Abbreviations

| Abbreviation | Description |
|---|---|
| AoO | Area of Occupancy |
| DBH | Diameter at Breast Height |
| EoO | Extent of Occurrence |
| GPA | Generational Persistence Assessment |
| IUCN | International Union for the Conservation of Nature |
| LGA | Local Government Area |
| MCP | Minimum Convex Polygon |
| NSI | North Stradbroke Island |
| PKFT | Preferred Koala Food Tree |
| PKH | Preferred Koala Habitat |
| QLD | Queensland |
| RCC | Redlands City Council |
| RCC LGA | Redlands City Council Local Government Area |
| RE | Regional Ecosystem |
| REDD | Regional Ecosystem Description Database |
| SE | Standard Error |
| UTM | Universal Transverse Mercator |

## CoLS


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## Executive Summary

The Redlands Coast LGA is located to the south of the Brisbane metropolitan area in south-east Queensland and inclusive of its constituent islands, encompasses a land surface area of 51,951 ha. Koalas have a long history of occupation in the Redlands Coast, the first official record being reported from North Stradbroke Island (NSI) in 1943. Analyses of 23,310 koala records from mainland Redlands Coast and NSI have indicated no significant change in the key range parameters *Extent of Occurrence* and *Area of Occupancy*[1] when records for the time period 1943 – 1999 are compared to those of the three most recent koala generations 2000 – 2017. Across the Redlands Coast, the current *Extent of Occurrence* for the three most recent koala generations covers the entire mainland area and the northern half of NSI respectively, while the associated *Area of Occupancy* estimates for both areas implied ~ 70.81% and 23.1% of available habitat respectively. Areas of Generational Persistence are also extensively distributed across the mainland areas of the Redlands Coast, while on NSI they are most evident in areas around Point Lookout, Amity and Dunwich. Despite little change in the key range parameters over the last three koala generations, there has been a progressive and ongoing decline in the frequency of reporting koalas from areas of mainland Redlands Coast since a peak in 2000.

Analysis of 10,597 records collated from the Moggill Koala Hospital for the period 1997 – 2017 reveals that disease, vehicle-strike and dog attack are the primary contributors to koala mortality across the Local Government Area (LGA). Deaths from disease accounted for ~ 57% of all known mortalities, while collectively vehicle-strike and domestic dog attack accounted for ~40% of the remaining mortalities. Further analyses of vehicle-strike data identified a number of long-standing black spots for koalas in the Redlands Coast, particularly along Mount Cotton Road, Duncan Road and Redland Bay Road intersections in Capalaba. The incidence of domestic dog attack, occurring at highest density within the most urbanised parts of the Redlands Coast, has remained proportionally constant over time. The rates of anthropogenic mortality drivers, including domestic dog attack and vehicle-strike, both individually and collectively have the potential to drive ongoing koala population decline across the LGA. However, for mainland Redlands Coast koala populations at least, the mortality data is most notable for the large numbers of 'diseased' koalas that have been euthanised in recent generations, the numbers of which we consider to have been the primary driver of a reduction in koala density over the last three koala generations, with at least 2,292 koalas having been removed from the population and euthanized between 1997 and 2014, a number that exceeds

[1] Terms are defined in the methods section of this report.

that known to have been collectively killed by vehicle-strike and domestic dog attack over this same time period.

Based on studies undertaken locally and elsewhere in south-eastern Queensland, knowledge regarding the Eucalypt species most preferred by the Redlands Coast koalas formed the basis of a hierarchical process of koala habitat classification based on information regarding the presence/absence/abundance of these Preferred Koala Food Tree (PKFT) species within the 26 Regional Ecosystems (REs) currently mapped as occurring within the Redlands Coast. This process enabled an estimate of the amount of remaining areas of Preferred Koala Habitat (PKH) of 8,346 ha on mainland Redlands Coast and 2,726 ha on NSI, the latter estimate reflecting a corrected preliminary extent once mapping anomalies implying the potential presence of PKFTs in RE 12.2.10 was resolved to the contrary by field survey.

Field survey involved application of Rapid-SAT protocols at approximately 1 km intervals across the mainland and on NSI. On the mainland and subject to landholder permissions, 59 field sites were surveyed, 39 of which contained one or more species of PKFT. Twenty-seven of these 39 field sites contained evidence of habitat utilisation by koalas in the form of diagnostic faecal pellets, these data enabling a field-based utilisation/occupancy estimate of 69.23% of the total area of available habitat, this measure concordant with that predicted by records analysis. Conversely, no evidence of koala habitat utilisation was recorded at site level from the remaining 20 field sites that did not contain PKFTs. The greater proportion of active sites was aggregated in the southwestern corner of mainland Redlands Coast. Only one koala was sighted in the 23.86 ha of transect searches that were undertaken at each of the 39 field sites which resulted in a low density estimate of 0.04 koalas $ha^{-1}$. Forty field sites were sampled on NSI, of which only 8 were subsequently determined to contain PKFTs, and all of these contained evidence of habitat utilisation by koalas in the form of diagnostic faecal pellets. One koala was sighted in the collective 6.64 ha of transect searches that were undertaken at each field site to imply an overall koala density estimate for NSI of 0.15 koalas $ha^{-1}$. Field survey data combined with knowledge about the amount of remaining PKH enabled a koala population estimate of approximately 754 koalas to be calculated for the Redlands Coast, including a 'best-estimate' of 345 ± 74 koalas (95% CI) for mainland Redlands.

Vegetation data collected at each of the sampled field sites enabled an overall determination of the accuracy of the RE mapping to be estimated at approximately 65.10% for mainland Redlands Coast and 82.76% for NSI. While this outcome warrants ongoing revision and consequent updating of RE mapping across remaining vegetated areas of mainland Redlands Coast at least, the extent to which the inaccuracies may serve to influence the extent of PKH on the mainland remains unknown, nor can it be accurately determined by this report.

The decline in reporting rate of koalas from mainland Redlands Coast since 2000 coupled with a best estimate population size of ~ 345 koalas presents a sobering trend for reflection given the certainty demonstrated from historical koala hospital admissions and sightings records of a koala population that numbered in the thousands less than two decades ago. Of particular interest is that outcomes obtained by both the records analyses and field survey are at odds with current paradigms of decline / conservation status that consider reductions in the Area of Occupancy as the most appropriate measure of conservation status. Paradoxically, both the records analysis and independent field survey results imply that optimum rates of habitat utilisation / occupancy by koalas in mainland Redlands Coast are being maintained. This outcome is at odds with other available data for declining koala populations from other areas of eastern Australia because it implies that a decrease in koala density, as opposed to occupancy, best explains the decline in reporting rate across mainland Redlands.

In contrast to the situation on mainland Redlands Coast, the NSI koala population appears to be stable and expanding it's currently known historical range and thus represents an opportunity for management to learn and gain insight into the nuances of koala conservation biology and population management. The NSI koala population has a long history of residency and clearly manages to maintain high occupancy rates and growth potential in the presence of disease, vehicle-strike and domestic dog attack, as well as periodic large-scale fire events. In considering the history of this dynamic we see a population that has thus far demonstrably withstood the test of time with minimal human intervention. In acknowledging this and in the presence of new genetic information from the concurrently undertaken study by University of the Sunshine Coast, we foresee inbreeding as the most likely longer-term management consideration given that the major influence on maintenance of genetic diversity on NSI – fire, its causes, consequences and management – invariably involves a strong anthropogenic element. We speculate that assessment of the koala gene pool on NSI may identify the need for carefully screened genetic supplementation over time in order to avoid issues associated with progressive bottlenecking effects, disease management and small population paradigms.

While well intentioned, the dis-proportionately high disease-mediated mortality rates that occur on mainland Redlands Coast requires review in terms of current policy regarding the euthanasia of koalas deemed to be diseased. As evidenced by the records analysis, the proportional reporting rates of diseased koalas has increased, indicating that euthanasia as a means of disease control has not had a positive impact in terms of lowering the rates of disease across mainland Redlands Coast. Supported by studies from Australia and overseas, there are also a number of valid ecological reasons why the practice of euthanising koalas deemed to be diseased requires review, including considerations relating to the imposition of a perception-based selection pressure on what is increasingly accepted as a dynamic immunological interaction, the loss of genetic diversity and the potential for population collapse through processes of social dissolution.

Given the preceding considerations, recommendations arising from the project have been limited to four key actions, the lack of commitment to which will likely see the ongoing decline and potential loss of koalas from mainland areas of the Redlands Coast within the foreseeable future if the current trend implied by the rate of decline in reporting rate continues. Of equal weighting and hence in no particular order of priority, these recommendations are as follows:

1. Establishment of a LGA wide monitoring program involving the creation of permanent monitoring points that can be resampled on a regular basis so as to inform on changes in both the occupancy rate and koala density changes over time,
2. A request to Government urging the need for a review of protocols and practices that currently relate to the euthanasia of koalas determined to be diseased,
3. Immediate attention to reduction of vehicle-strike potential at designated vehicle-strike black spots, and
4. Development of a strategic plan to minimise negative impacts upon koala population(s) occupying the south-western corner of mainland Redlands Coast and immediately adjoining habitat areas in the Logan City LGA.

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# 1. Introduction

The koala (*Phascolarctos cinereus*) is listed as a vulnerable species for purposes of both the Queensland Government's *Nature Conservation* (NC) *Act 1992* and the Commonwealth Government's *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999*. In the Redlands Coast, koala populations occur both on mainland areas and on North Stradbroke Island (NSI). The koala is the faunal emblem of the Redlands Coast and has been a long-standing focus of community interest and engagement; accordingly matters affecting koala conservation and welfare are of paramount interest (RCC 2016).

Historical records highlight the enduring presence of the koala as ubiquitous in the Redlands Coast. Additionally, the Redlands Coast is recognised as a population stronghold for koalas within the broader area known generally as the 'Koala Coast' which comprises the entire mainland area of the Redlands Coast, the eastern area of Logan City and the south eastern area of Brisbane City (RCC 2016). Recent scientific reports (DERM 2009; Rhodes *et al.* 2015) indicate that Koala Coast koala populations have declined by approximately 64% - 80% since the mid-90s due to multiple threatening processes including habitat loss, disease, vehicle-strike and dog attack.

Redland City Council (RCC) continues to address community concern about koalas through an ongoing commitment to maintaining and protecting the species within the boundaries of the RCC Local Government Area (LGA). Recently, a review of RCC's 2008 Koala Policy and Strategy resulted in the development of the *Redland Koala Conservation Strategy 2016* and *Redland Koala Conservation Action Plan 2016 - 2021*, both of which aim to further guide management actions so as to retain a viable koala population and conserve and manage suitable habitat, both on the mainland and on NSI. The Action Plan's main objectives can be refined to four key themes: (1) decisions based on science, (2) protect and improve koala habitat, (3) reduce koala deaths, and (4) community making a difference. To plan future conservation actions and measure all changes accurately, RCC requires an evidence-based assessment of the current koala population, hence a stated intention to gain a better understanding of such things as koala health, birth rate, emigration, immigration and survival rates across the LGA. As such, a comprehensive assessment of the koala population and associated habitat requirements is required.

The range parameters *Extent of Occurrence* (EoO) and *Area of Occupancy* (AoO) are two measures pertaining to the spatial distribution of a species, the EoO being that area encapsulating the outermost limits of the area in which the species can be found, while the AoO is the area within the EoO in which the species actually occurs (Gaston 1997). Additionally, historical records can be used to examine the persistence of koalas over time. Generational Persistence Assessment (GPA) is used to describe this process which examines the data for records of koalas reoccurring in a localised area over sets of three consecutive koala generations, so identifying the likely presence of contemporaneous source populations. Subject to the availability of ancillary information, another practical application of historical records analyses is to examine trends over time in terms of the type, locations and scale of key threatening processes (*e.g*. vehicle-strike, dog attacks) within a given area.

This project amongst others will be the first of several measures intended to address the objectives in the Action Plan. Specifically, this project focuses on matters pertaining to (1) koala distribution and abundance, and (2) the evaluation of existing and potential koala habitat. This information will be used to assist development of a conservation plan for the Redlands Coast koala populations.

### 1.1. Objectives

The purpose of this project was to utilise historic koala records obtained from community and government sources, in combination with independent field survey, to inform RCC about trends in koala distribution. Specifically, this work entailed:

- Examining trends in the geographic distribution and abundance of koalas over time by way of analysing historical records,
- Creating population threat profiles to identify the relative hazards posed by domestic dog attack, vehicle-strike, disease and other factors,
- Identifying the locations (where possible) of local source populations using a combination of records-based analyses and field survey to verify potential extent,
- Providing estimates on koala population size, and
- Evaluating existing and potential koala habitat.

## 2. Methodology

### 2.1. Study Area

The Redlands Coast Local Government Area (hereafter referred to as the Redlands Coast) is located south of the Brisbane metropolitan area in south-east Queensland and occupies a combined land surface area of 51,951 ha. Spread along the southern coast of Moreton Bay, the Redlands Coast includes 12 mainland suburbs from Thorneside in the north and Redland Bay in the south to Mount Cotton / Sheldon in the west. The Redlands Coast also includes seven off-shore islands, of which the largest and most easterly is North Stradbroke Island (NSI). Land uses within the Redlands Coast include urban and rural-residential type developments, water reserves, parks and reserves, poultry farms, viticulture and extractive industries.

Pedologically, the Redlands Coast comprises a range of substrates and soil landscapes ranging from aeolian sands and marine sediments to uplifted metasediments and deep red kraznozems, the latter giving rise to the local 'Redlands' name. In addition to its role in supporting the conservation of marine communities including internationally significant wetlands, the Redlands Coast contains a diverse array of terrestrial vegetation communities in the form of coastal heathlands, Eucalyptus woodlands and forests.

## 2.2. Koala records

Several data sets of historical koala records were provided by RCC for evaluation, each of which were variously linked and / or overlapped with records contained in the Atlas of Living Australia and/or Wildnet and/or KoalaBase (Mogill Koala Hospital database), as well as radio tracking records from NSI (Cristescu, 2011). Once the extent of the relationships between these records was determined, a final data set was merged and uploaded into a Microsoft Access database where the records were again checked for duplication and spatial context. Records that were located in water a long distance from land (*i.e*. Moreton Bay or ocean) were removed from the final data set of mainland records that was used for analysis purposes; however, those that were located in water but otherwise within the 2 km grid that overlay the historical Extent of Occurrence on NSI (see below) were retained, because they were clearly the result of a minor spatial error associated with the GPS transcription point.

The resulting data sets for both mainland areas of the Redlands Coast and NSI were then partitioned to enable comparisons *post* 2000 (the time frames 2000 – 2005, 2006 – 2011, 2012 – 2017 approximating the time intervals for the most recent three koala generations, the measure of which is known to be approximately six years (Phillips, 2000)). This approach was taken so as to be able to express the results of analyses in the context of the International Union for the Conservation of Nature (IUCN) criteria that place weight on the concept of population change over a period of three (taxon-specific) generations (WCUSSC 1994).

### *2.2.1. Extent of Occurrence (EoO)*

The EoO is the area contained within the shortest continuous boundary that encompasses all species records for a defined time period and locality and is typically represented as the area enclosed by a Minimum Convex Polygon (MCP) constructed by connecting the outer-most koala records where no internal angle is greater than 180 degrees. However, there are cases where an alpha-hull (also known as a Minimum Convex/Concave Polygon) will better estimate the EoO (Burgman & Fox, 2003). The application of this latter approach occurs mainly when large tracts of otherwise unsuitable habitat are incorporated in the polygon due to a few records located on the extremities.

The following EoOs for both mainland and NSI koala populations were determined as follows:

a) All koala records (Historical EoO)
b) Koala records from the date of first record to 1999,
c) Koala records for the most recent three koala generations (2000 – 2017).

### *2.2.2. Area of Occupancy (AoO)*

The AoO is a measure of record heterogeneity across the landscape and as such estimates the actual area within the EoO that is occupied by the taxon of interest, reflecting the fact that a species will not usually occur throughout the entire EoO. Historical koala records must be carefully considered when estimating the AoO because of their tendency to reflect observer density more so than koala density, the latter being best assessed via more systematic, unbiased survey effort. In most areas, there is also a tendency for the reporting rate to change over time. Consequently, and unless corrected for during analyses such as that detailed in the following paragraph, range parameters such as AoO can potentially miscalculate the scale of any change that has occurred over time.

In order to estimate the AoO, a fixed-grid overlay[2] constrained by the boundaries of the historical EoO was used to create a series of cells for sampling purposes, the primary assessment mechanism being whether a koala record for the period being investigated was either present or absent within a given cell, as opposed to the numbers of individual records. In order to correct for changes in reporting rates over time, the numbers of koala records utilised for analysis in each instance was determined with regard to the smaller representative data set being analysed (*i.e.* if there were only 100 records in one of the two data sets being compared and the other was represented by 250 records, then 100 records were randomly selected from the latter data set). In order to normalise these data, fifty percent of the grid-cells in the fixed grid overlay were randomly selected through each of ten iterations for each time period of interest. Following each iteration, the number of cells within which koala records were present were recorded to estimate the proportion of the historical EoO that was occupied. The ten iterations enable a mean and central tendency measures of the AoO to be calculated for both time periods, the associated variances tested for homogeneity prior to being compared using two-sample *t*-tests.

Area of Occupancy estimates for mainland Redlands Coast and NSI koala populations were calculated for the following time periods:

a) from the date of first record to 1999, and
b) for the most recent three koala generations (2000 – 2017)

### *2.2.3. Generational Persistence Assessment (GPA)*

Koala records were examined for re-occurrence in the same localised area over time frames that extended beyond the life-spans of individual koalas. For the purposes of GPA, 'localised' was considered to be that area within each of the aforementioned grid cells that had been generated to support the AoO analyses. Generational persistence was then determined for each grid-cell based on

[2] 2 km x 2 km for NSI, 1 km x 1 km for the mainland

a requirement for the presence a no more than a single koala record for each of the three most recent koala generations 2000 – 2005, 2006 – 2011 and 2012 – 2017.

## 2.3. Review of Threatening Processes

We also reviewed records for the period 1997 – 2017 that had been collected by Moggill Koala Hospital (as provided to us by RCC) in order to examine trends, patterns and processes that may have some influence on long-term koala population viability, with a particular focus on issues such as disease, domestic dog attack and vehicle-strike, as outlined in the following sections:

### *2.3.1. Disease*

Records of koala disease were partitioned by year and diagnosis (where possible) prior to being examined for seasonal and annual trends using regression analyses and Mann-Kendall trend tests. Geographic patterns were examined in ArcGIS Pro by partitioning the records by koala generation dating backwards from the most recent year where the data set was complete, in this case 2017. For graphic purposes, resulting datasets were spatially intersected with a 500 m grid so that the distribution and densities of disease-related records within each resulting 25 ha square could be illustrated using a series of standardised gradation parameters.

On the basis of a cursory examination of the records, available data categories pertaining to disease were "*conjunctivitis / cystitis / wasted / sick – other*". There was no categorical classification of chlamydiosis and/or Koala Retro Virus (KoRV) *per se*, however the most prevalent clinical signs of chlamydial infection are conjunctivitis and/or urinary tract infection and/or reproductive tract infection (which is often asymptomatic). For the purposes of analysis, we assumed that animals presenting with conjunctivitis and/or cystitis were positive for chlamydia. In the absence of specific testing for chlamydia, results in this context are therefore indicative, rather than definitive.

Records of cystitis, conjunctivitis and wasted were examined via two-tailed *t*-test to determine if the sex of the individual, where data was available, influenced whether it was more likely to be euthanised.

### *2.3.2. Vehicle Strike*

Areas contributing a disproportionately greater number of vehicle-strikes were identified using the approach developed by Biolink (2017b), whereby road-strike outcomes are examined in terms of the number of road strikes $km^{-1}$ koala $generation^{-1}$. Cluster /black-spot identification was achieved by calculating the average Euclidian distance between each koala vehicle-strike and the five closest vehicle-strikes for each of the koala generations being considered. Central tendency measures were determined for the resulting data and the associated 95% confidence interval was utilised to define the distance parameter by which vehicle-strike data could be clustered. Vehicle-strikes that did not fall within clusters identified by this process were excluded from further analysis because they effectively represented geographically isolated events. For the purposes of cluster / black-spot identification, vehicle-strike data included all vehicle-related incidents that were reported, whether this was fatal or not.

Records of koalas killed by trains were mapped spatially and displayed by generation.

*2.3.3. Domestic Dog Attack*

Records were examined for changes over time using least-squares regression. Geographic patterns were examined in ArcGIS Pro by again partitioning records by koala generation dating backwards from the most recent year where the data set was complete, in this case 2017. In common with disease data, resulting datasets were spatially intersected with the same 500 m grid so that both the distribution and densities of domestic dog attack records within each resulting 25 ha square could be illustrated using a standardised gradation process.

## 2.4. Regional Ecosystem mapping

The Regional Ecosystem Description Database (REDD) mapping layer used for the Redlands Coast mainland was provided by RCC (named 'BIO_VEG_CMN_HABITAT2015_P'), whereas on North Stradbroke Island the Queensland Government's REDD mapping was used (named 'Biodiversity status of 2015 remnant regional ecosystems'). RE mapping provided the basis for field survey design and koala habitat categorisations. Because of this, some knowledge and associated estimate of underlying accuracy was considered necessary. Mapping accuracy can be estimated by considering floristic data recorded at each field survey site location with that of the RE descriptions that otherwise apply to the mapped polygon in which the site is located. To enable this measure, rapid vegetation assessments were undertaken at each field site by recording all observable species of the tallest-strata within a 25 m radius of the site coordinates for each field site. Abundance data for tallest-strata species were then collected by counting the closest standing live stems intersected by a line of sight along each of the cardinal and intermediate compass points (*i.e.* a maximum of 8 sampling points in total) from the central sampling point. The resulting data was then considered in the context of floristic information contained in both the REDD and associated Technical descriptions (https://publications.qld.gov.au/dataset/re-technical-descriptions).

In order to derive an overall accuracy estimate, polygons were scored as follows:

- '100%' (*i.e.* correctly typed) where there was agreement between the tallest stratum tree species recorded and the REDD and associated Technical description for that particular polygon as detailed by Queensland Government (2017),
- '50%' when the polygon appeared incorrectly typed but a corresponding community appeared within 100 m and/or the species was otherwise considered to be both diagnostic and a dominant component of the overstorey but was sub-dominant at the assessed site, or
- '0%' (*i.e.* not correctly typed) when no conformity was apparent.

An estimate of mapping accuracy along with an associated 95% Confidence Interval could then be determined by dividing the sum of scores by the number of contributing field sites.

## 2.5. Koala Habitat Classification

A four-tiered, hierarchical koala habitat classification involved assigning habitat quality classes based on the relative abundance (dominance) of Preferred Koala Food Tree (PKFT) species, the presence of which could be determined from the associated RE descriptions. Each of the classifications (**Table 2.1**) reflects differing koala carrying capacities of the associated vegetation communities, areas of 'Primary' Koala Habitat capable of sustaining high density populations (*i.e*. > 0.5 koalas $ha^{-1}$), whereas Secondary (Class C) / Marginal Koala Habitat can only sustain low density populations (*i.e*. < 0.1 koalas $ha^{-1}$). Collectively, 'Primary' and 'Secondary' habitat classifications function to identify areas of Preferred Koala Habitat (PKH).

Habitat categorisations were based on considerations relating to the presence/absence of PKFTs, which for the Redlands Coast comprisedthe following species:

- *Eucalyptus robusta* (swamp mahogany)*
- *E. resinifera* (red mahogany),
- *E. tereticornis* (blue (Forest red) gum),
- *E. microcorys* (tallowwood),
- *E. moluccana* (grey box), and
- *E. propinqua* and/or *E. major (*grey gums) including affiliated species such as *E*. *biturbinata* and/or *E. longirostrata*.

* Includes the naturally occurring *E. robusta* x *E. tereticornis* hybrid, often referred to *E. patentinervis*.

<u>**Note 1**</u>: Preferred Koala Food Trees (PKFTs) are a discrete suite of species in the Genus *Eucalyptus* which, as the term implies, are the subject of <u>preferential</u> utilisation (*i.e.* statistically significant levels of use by koalas when compared to the relative abundance of that tree species in the landscape being assessed). Techniques for identifying PKFTs include replicated Goodness of Fit tests that compare the proportion of tree species '*x*' occupied by radio-tracked koalas to that of the relative abundance of tree species '*x*' in the same study area (Phillips 1999) and/or statistical analyses of tree species / faecal pellet presence/absence data (Phillips *et al*. 2000; Phillips & Callaghan 2000; Phillips & Callaghan 2011). While casual observations of feeding behaviour and techniques such as cuticle-scale analyses can provide information about tree species being used by koalas in a given area, such data when presented in isolation (*e.g*. Woodward *et al*. 2008; Cristescu *et al*. 2011; Melzer *et al*. 2014) cannot readily be partitioned in terms of those tree species being <u>preferentially</u> utilised (as defined above) and those being the subject of more opportunistic levels of use.

The need to distinguish between PKFTs and other tree species used by koalas is important but all too often understated; vegetation communities without PKFTs simply cannot permanently sustain free-ranging koala populations, while the removal of PKFTs from within areas being utilised by koala's can result in nutritional stress, elevated levels of disease and a reduced reproductive output.

**Note 2:** The terms "Primary" and "Secondary" koala food tree species[3] as used in the classifications outlined in Table 2.1 below are based on the mathematical models of PKFT utilisation described by Phillips (2000b). Ongoing analyses of koala activity data from low nutrient substrates (Phillips and Allen 2014) has provided the basis for further partitioning of lower carrying capacity habitat types based on differences in the abundance of secondary food tree species. Specifically, vegetation communities wherein secondary food tree species are a dominant or co-dominant component of the tallest stratum support significantly higher koala activity levels (and hence a higher koala carrying capacity) than do vegetation communities wherein secondary food tree species occur at lower densities (Phillips and Allen 2014). This knowledge has informed the need to recognise a further habitat category - Secondary (Class C) Koala Habitat - as described below.

Due to intrinsic heterogeneity in some REs, it was considered useful in some instances to identify intermediate habitat categories. For example, RE 12.1.1 – Swamp She Oak (*Casuarina glauca*) Forest most commonly occurs as monoculture without PKFTs and hence the appropriate habitat categorisation from a koala habitat perspective would be "Other". However, in some areas and for a variety of reasons, RE 12.1.1 may contain PKFTs such as Blue (Forest red) gum and/or swamp mahogany as localised or occasional components of the overstorey. To recognise this possibility, such REs were categorised as "Other/Secondary Class A" or other combinations as appropriate, the hybrid classification simply recognising first-up the most commonly occurring form of the habitat from a koala's perspective, while also acknowledging that within it there will be localised habitat areas wherein PKFTs may be present.

**Table 2.1**. Four-tiered koala habitat classification hierarchy criteria as applied to REs mapped within the Redlands Coast.

| Koala habitat type | Classification criteria |
|---|---|
| **Primary koala habitat** | Forest and/or woodland REs occurring on soils of medium to high nutrient value whereupon primary PKFTs are dominant or co-dominant components of the tallest stratum. |
| **Secondary (Class A) koala habitat** | Forest and/or woodland REs occurring on soils of medium to high nutrient value whereupon primary PKFTs are sub-dominant components of the tallest stratum. |
| **Secondary (Class B) koala habitat** | Forest and/or woodland REs occurring on soils of low to medium nutrient value whereupon primary PKFTs are absent, the tallest stratum instead dominated or co-dominated by secondary food tree species only. |
| **Secondary (Class C) / marginal koala habitat** | Forest and/or woodland REs occurring on soils of low to medium nutrient value whereupon primary food tree species are absent and secondary food tree |

[3] Primary Food Tree requires preferential use by koalas to be significantly higher than other congeners with utilisation that is independent of size class (Phillips *et al*. (2000) refers) whereas a Secondary Food Tree also requires a level of use that is significantly higher than other congeners but with a utilisation model that is typically size-class dependent (Phillips and Callaghan (2000) refers).

| | |
|---|---|
| | species are sub-dominant components of the tallest stratum. |
| **Other** | Forest and/or woodland REs that do not contain PKFTs. |
| **Unknown** | Vegetation not currently mapped or described. |

## 2.6. Influence of Soil Landscape on use of PKFTs

Because the palatability of certain preferred food tree species by koalas is known to be influenced by soil type (Moore and Foley 2000; Phillips and Callaghan 2000), it cannot be assumed that the use of PKFTs, once known, will necessarily remain uniform across pedologically heterogeneous landscapes. Indeed, linear models for the PKFT tallowwood demonstrate utilisation as a ‘primary’ food tree (*i.e*. significant levels of utilisation by koalas occurring independently of size class) on medium to high nutrient substrates), but utilisation as a ‘secondary’ food tree (*i.e*. significant but size-class based levels of utilisation by koalas) on low nutrient soils (Moore *et al*., 2004). For this reason, the PKFT palatability decision path for the Redlands Coast was further refined based on consideration of PKFT occurrence on two coarsely aggregated soil landscape categories as follows:

i. Transferral, Alluvial, Swamp and Colluvial soil landscapes were deemed to be of MEDIUM to HIGH nutrient value; while
ii. Erosional and Meta-sedimentary soil landscapes typified by the presence of trees species such as spotted gum and grey gum were deemed to be of LOW to MEDIUM nutrient value.

## 2.7. Field Survey

### *2.7.1 Selection of field survey sites*

To ensure a uniformly widespread coverage of field survey effort, the mainland area of the Redlands Coast was overlain with a 1 km x 1 km point-based grid, each point becoming a potential field site where it occurred within an area that had been identified as potential koala habitat based on available RE mapping and associated descriptions that indicated the presence of one or more PKFTs as a component of the overstorey floristics.

NSI was initially overlain with a 2 km x 2 km point-based grid because of its larger size when compared to the mainland, but this was ultimately reduced to a smaller (1 km x 1 km) grid to better capture unburnt vegetation patches arising from a fire event in 2014. Potential field sites that resulted from this latter process were additionally afforded a 100 m buffer to enable adjustment to accommodate the impact of the fire event such that if coordinates for a planned field site fell within an area of PKH that was burnt by the 2014 fire but could be moved within the 100 m buffer to an unburnt area of PKH, then it was moved into that vegetation patch. Conversely, if the entirety of the buffered area was impacted by fire, the site was removed for sampling purposes.

Universal Transverse Mercator (UTM) coordinates were determined for each corresponding field site and were uploaded into hand-held GPS to enable location in the field.

### 2.7.2 Field assessments

Field assessments were undertaken using Rapid-SAT sampling protocols which are reliant upon the presence of diagnostic koala faecal pellets within a prescribed search area of 1 m around the bases of PKFTs. The Rapid-SAT approach offers a time and cost effective survey technique predicated by knowledge that in areas being utilised by koalas, there is a 50% probability of faecal pellets occurring within 1 m of the base of any PKFT ≥ 300 mm diameter at breast height (DBH) (Phillips and Wallis 2016).

In the field, some flexibility with site placement (+/- 25 m) was permitted so as to optimise the numbers of PKFTs being sampled at any point. Assessment at a given sampling point ceased when one or more koala faecal pellets had been detected. Conversely, if no pellets were detected, sampling ceased once a minimum of 5 to maximum of 7 PKFTs had been assessed, these numbers affording a high level of statistical confidence (*e.g*. 95% or 99% respectively) that koalas were not using habitat in the immediate vicinity (**Table 2.2**).

**Table 2.2**. Binomial expansion showing 'Q' (% confidence of 'koala absence' at an individual Rapid-SAT site) based on the numbers of sampled PKFTs beneath which no koala faecal pellets have been detected. Expansion is based on knowledge that in areas being utilised by koalas, there is a 50% probability of one or more koala faecal pellets being present within 1 m from the base of each PKFT ≥ 300 mm DBH that has been sampled.

| No. of PKFTs | P (probability of success) | Q (%) |
|---|---|---|
| 1 | 0.500 | 50% |
| 2 | 0.250 | 75% |
| 3 | 0.125 | 87.5% |
| 4 | 0.063 | 93.7% |
| 5 | 0.031 | > 95% |
| 6 | 0.016 | > 95% |
| 7 | 0.008 | > 99% |

### 2.7.3 Koala population size

At each field site we undertook direct counts of koalas within both 25 m fixed-radius and 250 m x 40 m (1 ha or approximations thereof) transect searches (*sensu* Dique *et al.* 2003) centred on each sampling point so as to obtain a koala density estimate which could then be applied in conjunction with understandings of occupancy and the extent of PKH to derive a koala population estimate. Searches were typically undertaken using two observers walking ~ 10 m apart along one side of the transect alignment before returning along the other. In effect, this results in a three-person search effort while habitat located around the central line is actually searched twice.

We used two methods to derive population estimates:

1. Koala density estimate (± SE) from all sites with PKFTs, extrapolated across the estimated amount of PKH, and
2. A koala density estimate derived from occupied sites only (± SE), multiplied by the estimated amount of PKH.

The majority of data associated with the field survey components of this report were enumerative. Because of this, most data were assumed to follow a Poisson distribution. Hence and unless otherwise specified, the Standard Error (SE) of the sample was estimated using the following term:

$$SE = \sqrt{pq/n} \qquad \text{(Eqn 1)}$$

Where:

$SE$ = standard error of the sample

$p$ = the sample proportion

$q = 1 - p$

$n$ = sample size

# 3. Results

## 3.1 Koala Records

### *3.1.1 Mainland*

Twenty-three thousand, three hundred and ten (23,310) koala records were extracted from the data sets provided by RCC, the final merged data set collectively comprising records from the Atlas of Living Australia, Koala Base (Moggill Koala Hospital) and Wildnet databases. The chronological distribution of these records is illustrated in **Figure 3.1** The earliest mainland Redlands Coast record is from 1954 from south of Moreton Bay Road near Capalaba. The spatial distribution of the records (**Figure 3.2**) occurs at highest density in the northern part of the LGA where observer density was correspondingly higher, with lower densities in the south-west where observer density is lowest. Over the time period 1954 - 2017, the reporting rate of koalas peaked in 2000 and has progressively decreased thereafter. The upper 95% confidence interval of the regression analysis implies that the reporting rate will reach zero in 2038 ($R^2$ = 0.82, $F$ < 0.01).

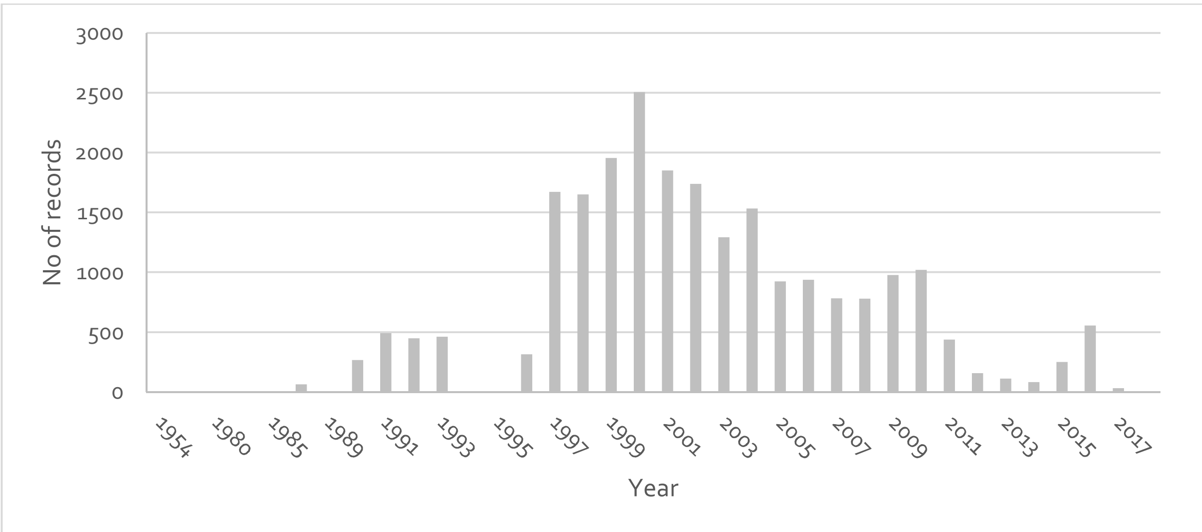



**Figure 3.1.** Frequency histogram detailing chronological distribution of 23,310 koala records for mainland areas of the Redlands Coast for the period 1954 – 2017.

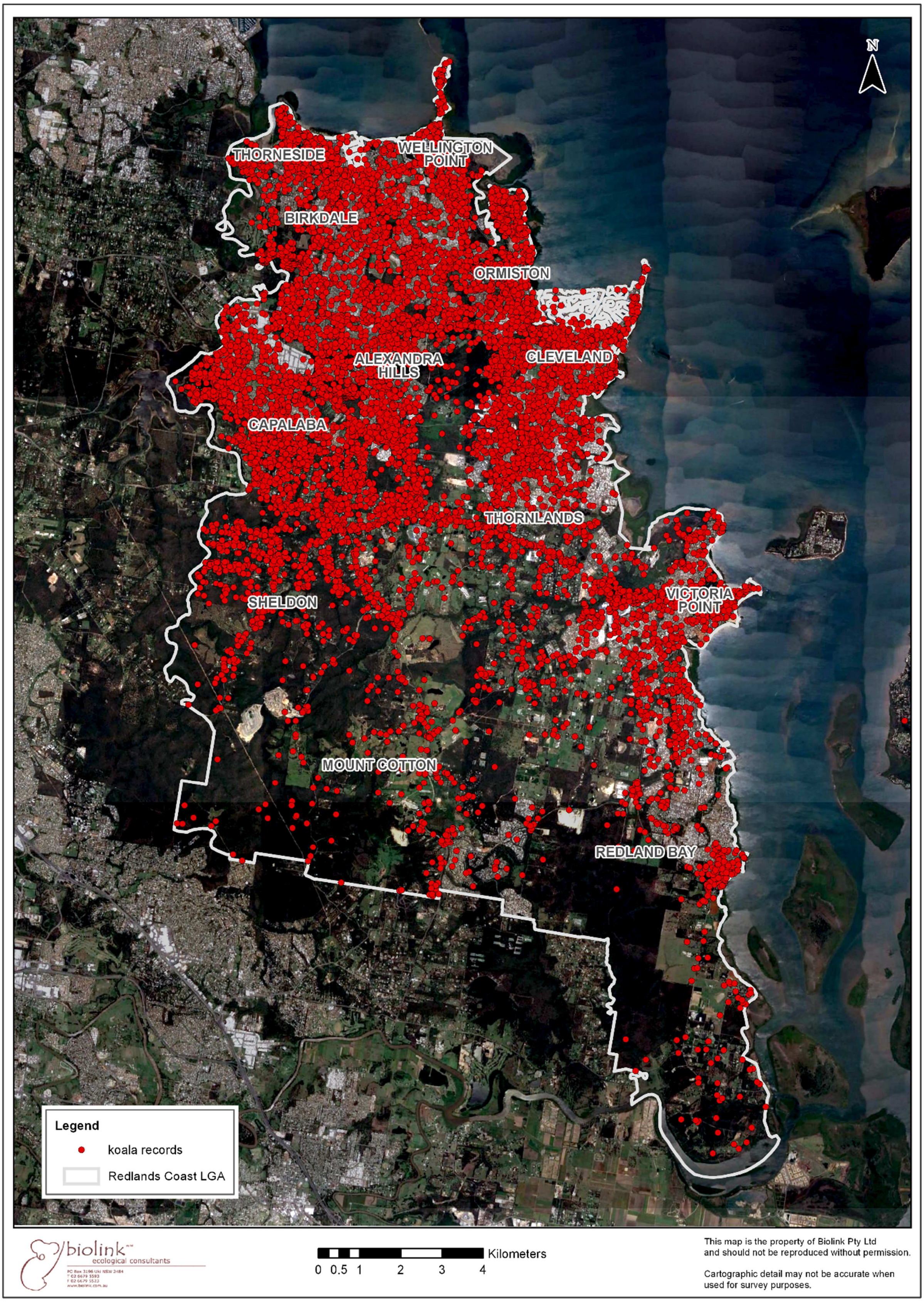



**Figure 3.2**. Distribution of 23,310 koala records (red circles) for mainland areas of the Redlands Coast from the date of first record in 1954 through to 2017.

*3.1.2 North Stradbroke Island*

One thousand one hundred and sixty-six (1,166) koala records for NSI were collectively merged from the Atlas of Living Australia, Koala Base (Moggill Koala Hospital) and Wildnet databases, in addition to that arising from the radio-tracking work of Cristescu *et al*. (2011), the chronological distribution of which is illustrated in **Figure 3.3**. The earliest record for NSI stems from 1943 from Point Lookout just south of the end of East Coast Road. The spatial distribution of the records (**Figure 3.4**) has the highest density around the northern and eastern coastline. The spike in the reporting rate of koalas in 2009 is singularly due to the large number of records provided by the radio-tracking work of Cristescu *et al*. (2011).

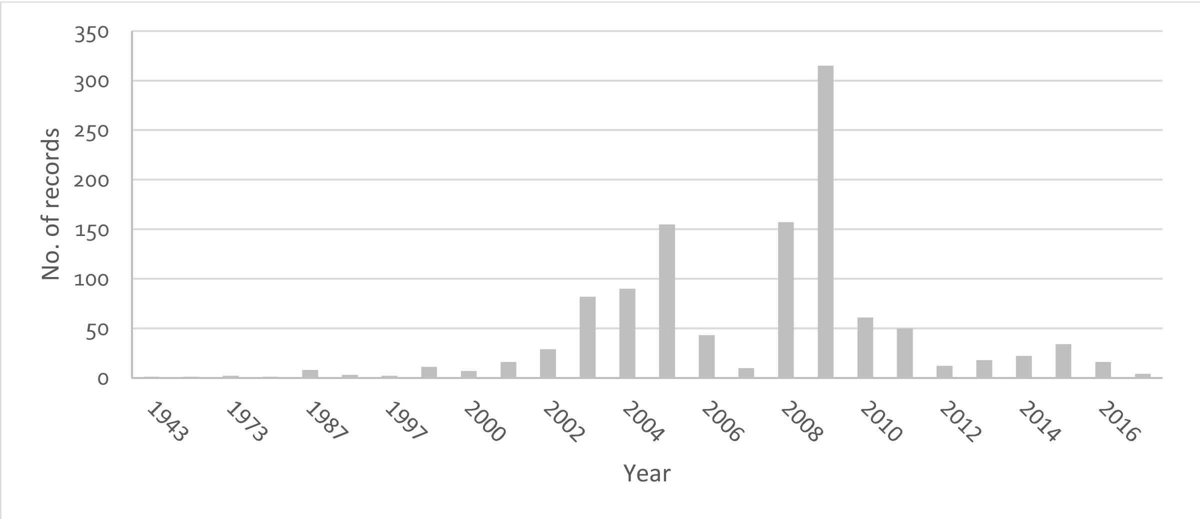



**Figure 3.3.** Frequency histogram detailing chronological distribution of 1,166 koala records for NSI over the period 1943 – 2017.


**Figure 3.4.** Distribution of 1,166 koala records (red circles) across NSI over the period 1943 - 2017.

## 3.2 Extent of Occurrence

### *3.2.1 Mainland*

The records indicate an historical EoO of koalas across mainland Redlands Coast of approximately 27,911 ha, this being the area captured by a Minimum Convex Polygon with vertices that intersect the outermost koala records in the dataset for the time-period 1954 – 2017 (**Figure 3.5**). The distribution of these records further imply that the EoO has changed little over time, being estimated at 27,490 ha for the period 1943 – 1999 and 27,386 ha for the three most recent koala generations (2000 - 2017) (**Figure 3.6**).

### 3.2.2 *North Stradbroke Island*

The majority of koala records were restricted to the northern and western periphery of NSI and for this reason the alpha-hull approach was utilised, a threshold of 0.4[4] selected using the concave-hull tool of QGIS. This approach implied an historical EoO of koalas across NSI of approximately 13,799 ha, this being the area captured by a concave hull polygon with vertices that intersect the outermost koala records in the dataset for the time-period 1943 – 2017 (**Figure 3.7**). Records further imply that the EoO has more than doubled over time, having a size of 4,527 ha for the period 1943– 1999 and 13,448 ha for the most recent three koala generations (2000 - 2017) (**Figure 3.8**).

[4] Threshold of 0.4 and 0.5 was used because it was the minimum value that did not result in the creation of two discrete polygons for the time periods 1943-2017 and 1943-1999 respectively.

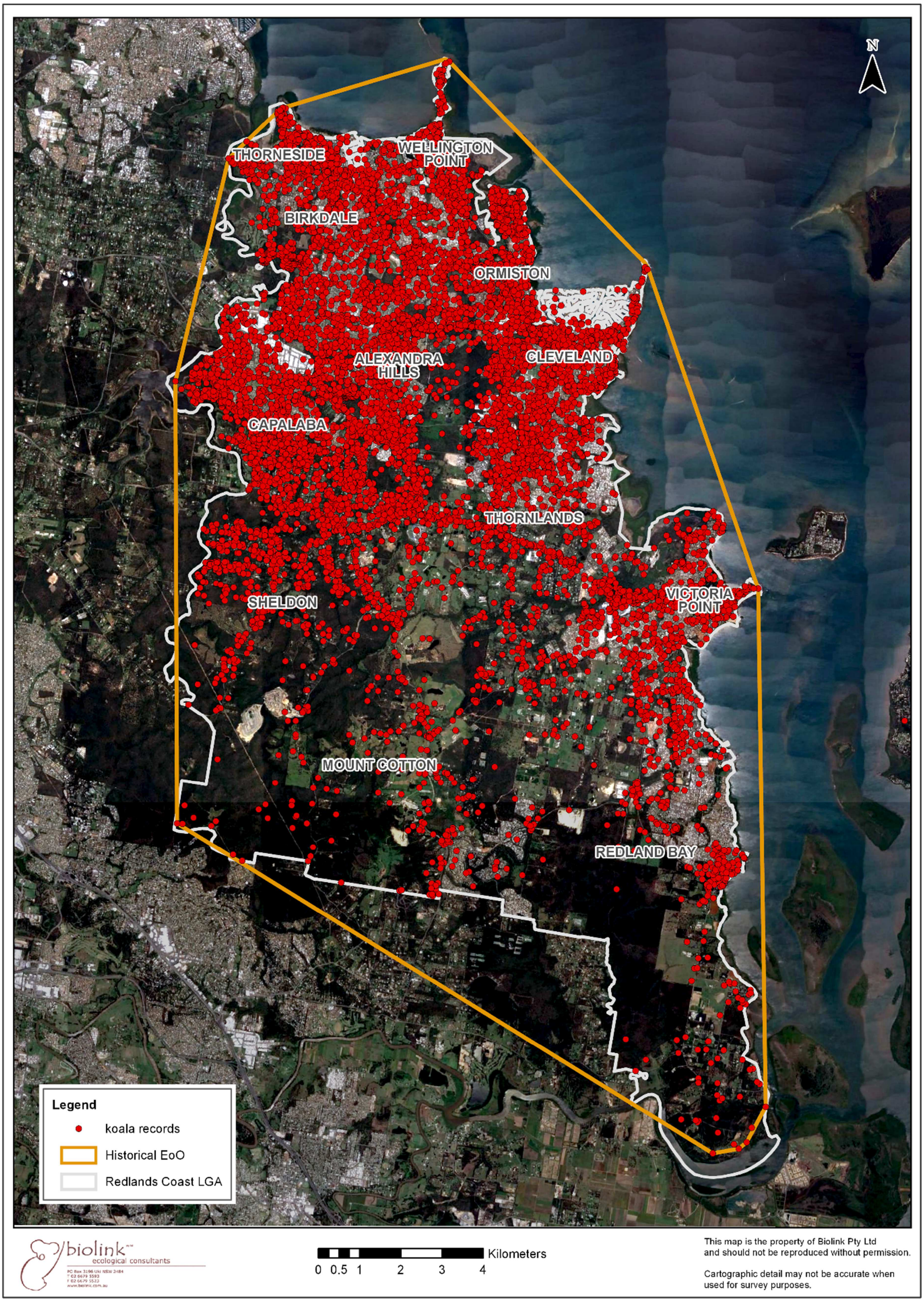



**Figure 3.5.** Historical Extent of Occurrence of koalas across mainland areas of the Redlands Coast from 1954 – 2017.

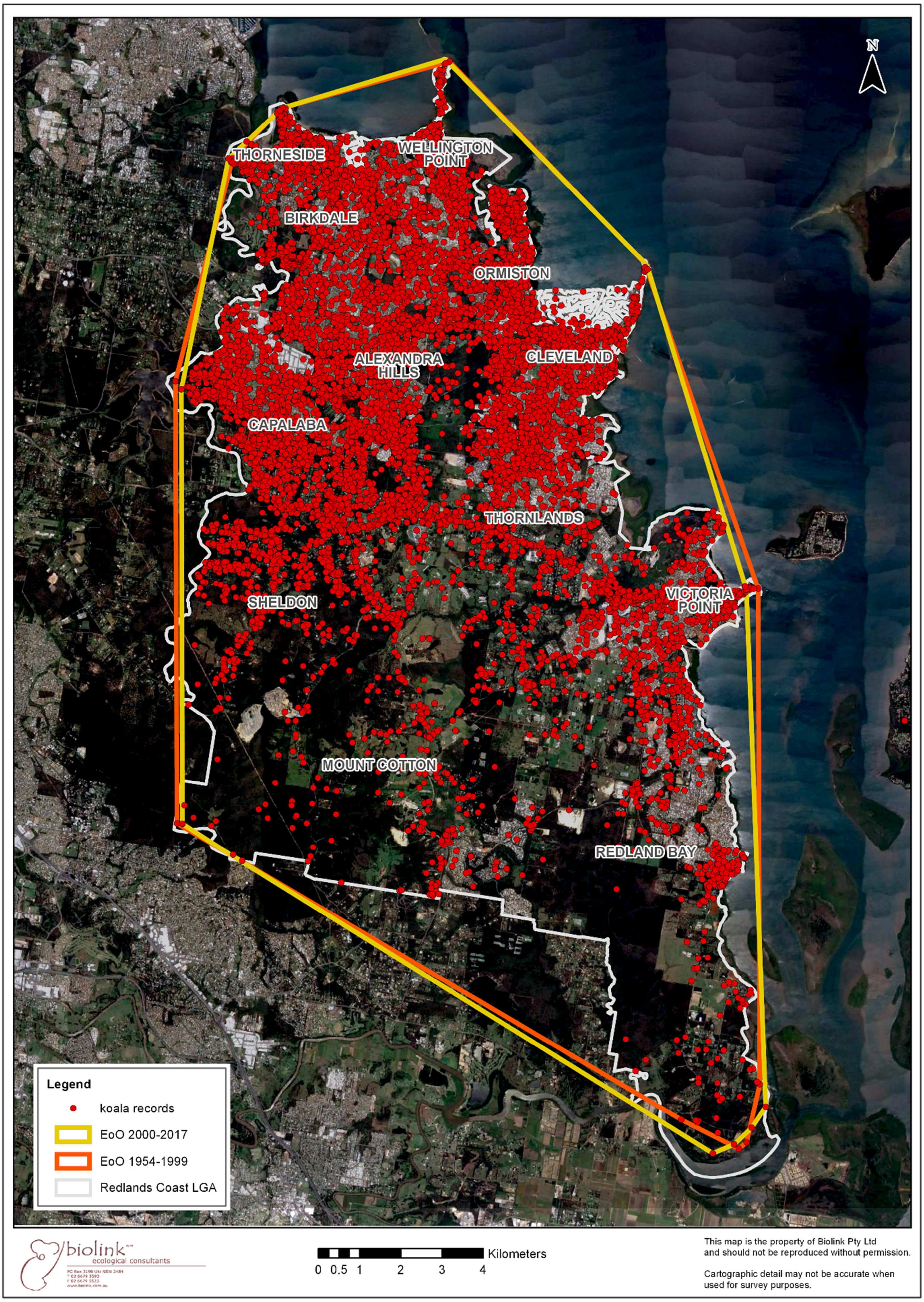



**Figure 3.6.** Extents of Occurrence on mainland areas of the Redlands Coast over the two time periods 1954 - 1999 (orange) and 2000 - 2017 (yellow), the latter representing the most recent three koala generations.


**Figure 3.7.** Historical Extent of Occurrence of koalas across NSI 1943 – 2017, here represented by a concave-hull polygon.

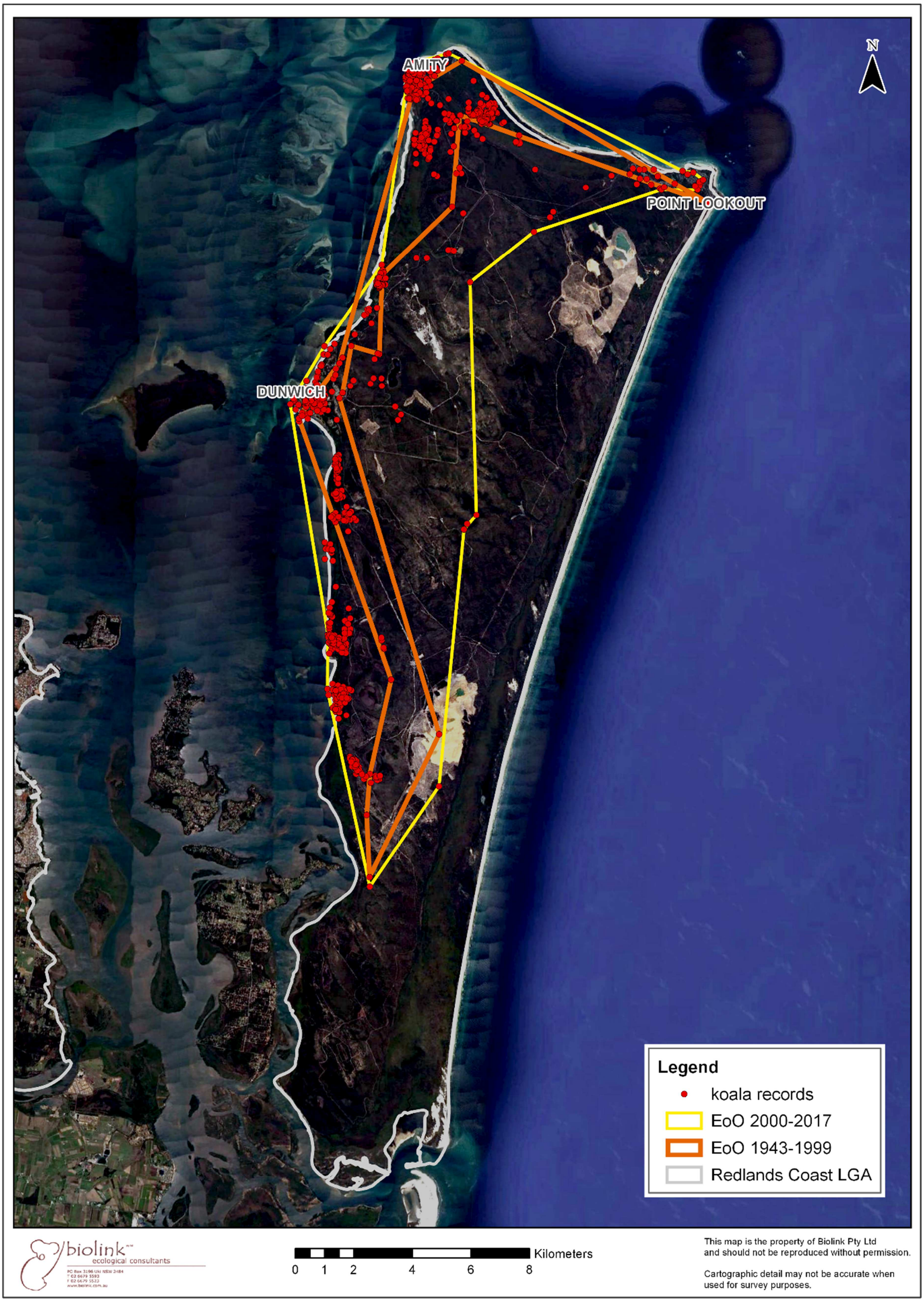



**Figure 3.8.** Extents of Occurrence of koalas on NSI over the two time periods 1943 - 1999 (yellow) and 2000 - 2017 (orange), the latter representing the most recent three koala generations.

## 3.3 Area of Occupancy

### *3.3.1 Mainland*

Two hundred and seventy-four (274) 1 km x 1 km grid-cells covered the historical EoO, the habitat occupancy / utilisation rate estimated from 9,953 records for the time-period 1954 – 1999 compared to a subset of 9,953 randomly selected records for the time-period 2000 – 2017. Randomly sampling 50% of the 274 grid cells within the historical EoO over 10 iterations for each of these two time periods returned the following results:

**1954 – 1999:** AoO estimated at 68.80% ± 0.95% (SE) of available habitat

**2000 – 2017:** AoO estimated at 70.81% ± 0.72% (SE) of available habitat

A comparative analysis of the data-sets informing the preceding outcomes implies that there has not been any significant change in the proportional amount of habitat being utilised by koalas when comparing the last three koala generations (2000 - 2017) to the period preceding this (1943 - 1999) (Levene's test: $F$ = 1.714, $P$ = 0.217, 9*df*; $t$ = -1.679, $P$ = 0.11, 18*df*).

### *3.3.2 North Stradbroke Island*

Fifty-seven (57) 2 km x 2 km grid cells covering the historical EoO were utilised for this analysis. The occupancy rate estimated from 29 records for the time-period 1943 – 1999, was compared to a subset of 29 randomly selected records for the time-period 2000 – 2017. Randomly sampling 50% of the 57 grid cells within the historical EoO over 10 iterations for each of these two time periods returned the following results:

**1943 – 1999:** AoO estimated at 20.69% ± 1.45% (SE) of available habitat

**2000 – 2017:** AoO estimated at 23.10% ± 1.55% (SE) of available habitat

A comparative analysis of the data-sets informing the preceding outcome implies that there has not been a significant change in the proportional amount of habitat being utilised by koalas on NSI when comparing the last three koala generations (2000 - 2017) to the period preceding this (1943 - 1999) (Levene's test: $F$ = 0.8840, $P$ = 0.429, 9*df*; $t$ = -1.137, $P$ = 0.270, 18*df*).

Because records provided by radio-tracking work of Cristescu *et al*. (2011) resulted in a spike in the reporting rate in 2009, a subsequent analysis was performed removing these 791 records to determine the extent of effect, if any, these records may have had on the AoO estimate. This approach again used the same parameters as the previous analysis, only this time with 29 randomly selected records from the (now) much smaller pool of records for the time period 2000 – 2017 being utilised. Randomly sampling 50% of the 57 grid cells within the historical EoO over 10 iterations for each of these two time periods returned the following results:

1943 – 1999: AoO estimated at 20.34% ± 2.08% (SE) of available habitat

2000 – 2017: AoO estimated at 18.62% ± 1.47% (SE) of available habitat.

The comparative analysis of the informing data-sets following removal of the radio-tracking data again implies that there has not been a significant change in the areas being utilised by koalas when comparing the last three generations (2000 – 2017) to the period proceeding this (1943 – 1999) (Levene's test: $F$ = 2.0061, $P$ = 0.157, 9*df*; $t$ = 0.676; $P$ = 0.508, 18*df*).

## 3.4 Generational Persistence Assessment

### *3.4.1 Mainland*

For the 3 koala generations covering the time period 2000 – 2017, 134 of the 274 1 km x 1 km grid cells reflecting the historical EoO contained one or more koala records for each of the three constituent koala generations 2000 – 2005, 2006 - 2011 and 2012 -2017 respectively, this result (*i.e*. 134/274) implying that approximately 50% of habitat on mainland Redlands Coast was supporting resident koala populations over this time period. **Figure 3.9** illustrates the widespread distribution of areas of generational persistence across mainland Redlands Coast. The largest area of generational persistence (11,700 ha) occurs in the vicinity of Wellington and Thorneside in the north to Sheldon and Victoria Point in the south.

### *3.4.2 North Stradbroke Island*

For the time period 2000 – 2017, 9 of the 58 2 km x 2 km grid cells comprising the historical EoO contained one or more koala records for each of the three constituent koala generations, this result enabling an estimate that approximately 18% of habitat on NSI was supporting local source/resident koala populations at three locations over this time period, the largest of which were located around Amity in the extreme north-western corner of the island, and at Dunwich to the south (**Figure 3.10**).

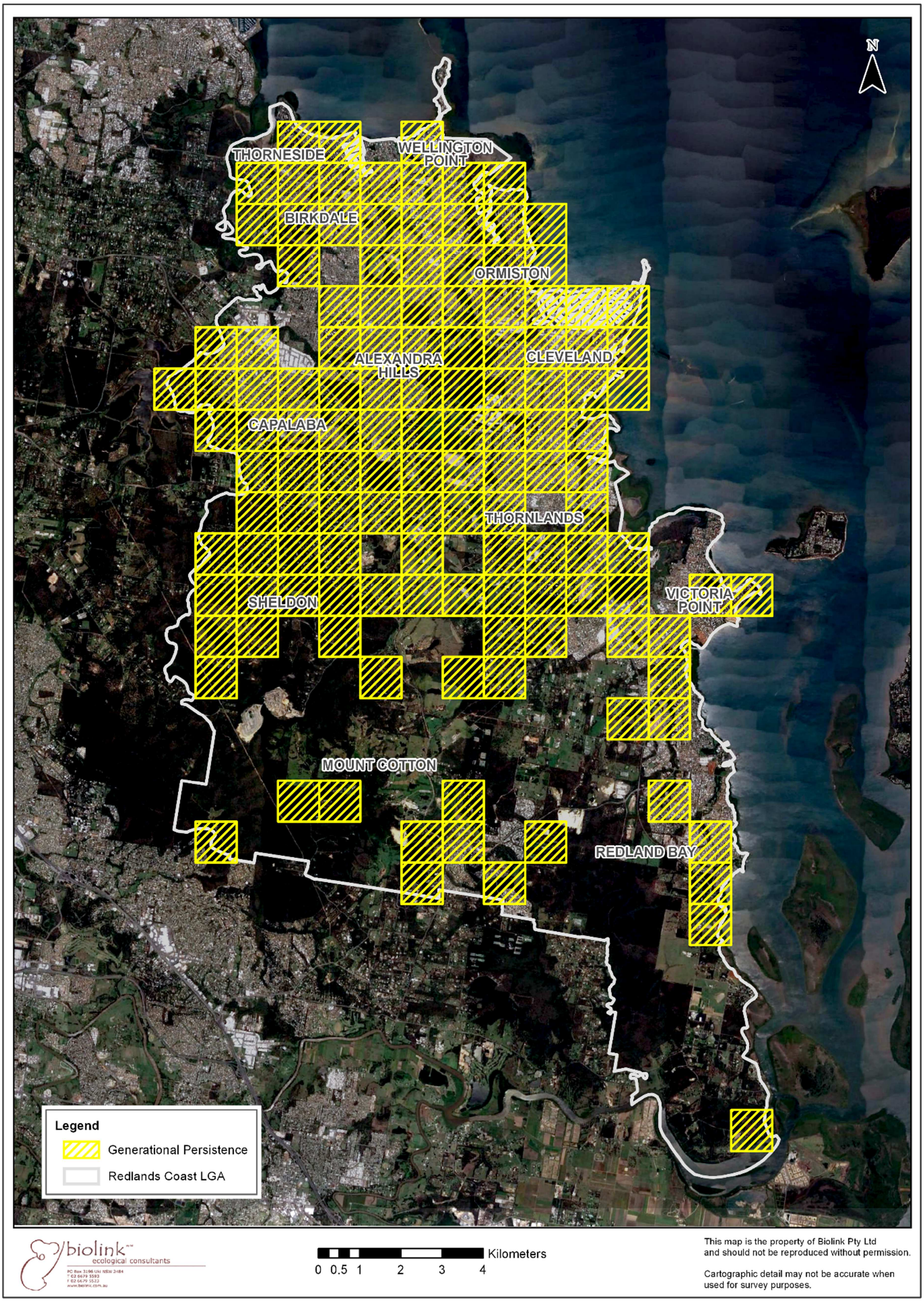



**Figure 3.9.** Areas of Generational Persistence (yellow diagonally-hatched cells) for the three most recent mainland koala generations (2000 – 2017).

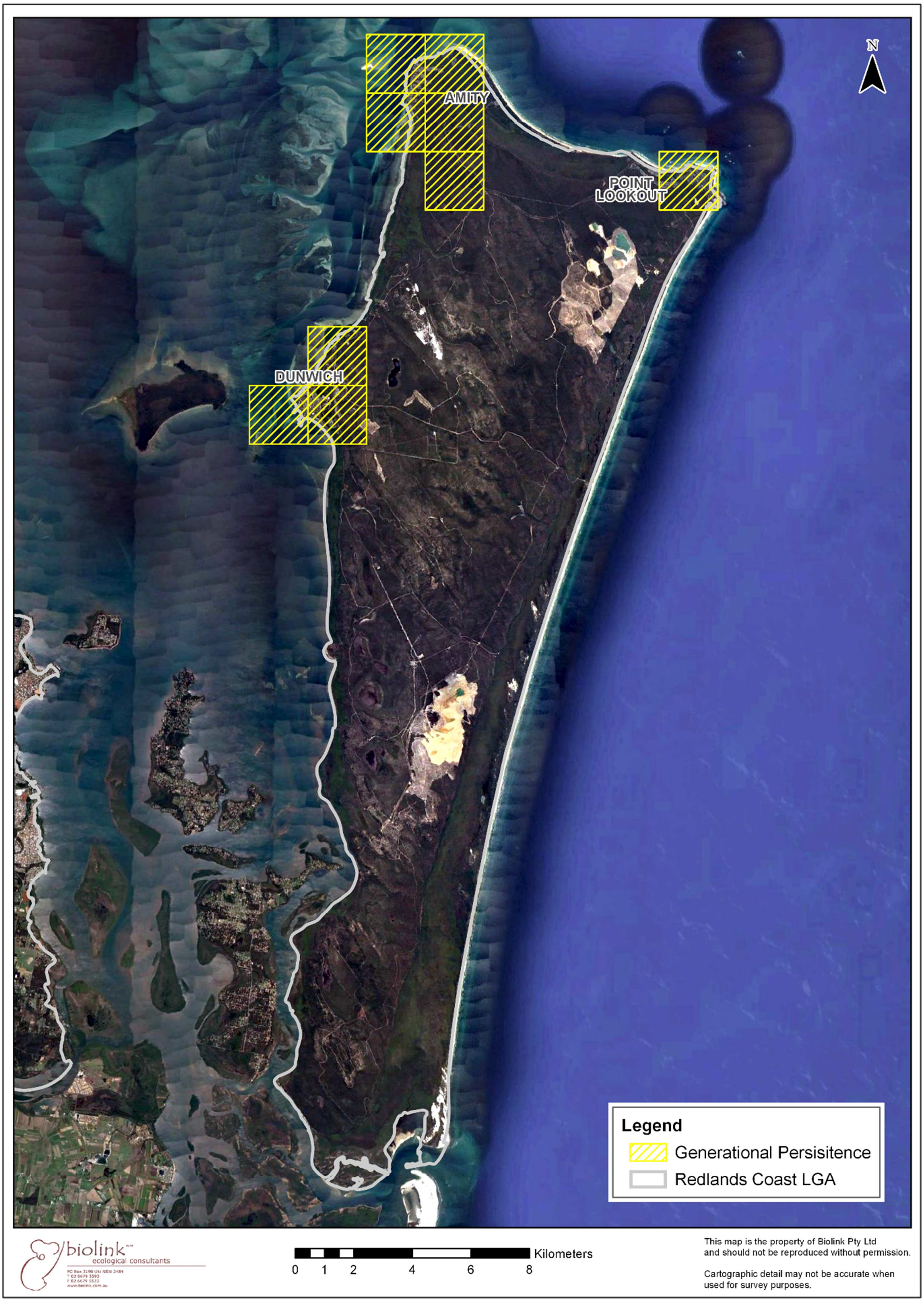



**Figure 3.10.** Areas of Generational Persistence (yellow diagonally-hatched cells) for the three most recent NSI koala generations (2000 – 2017).

## 3.5 Threatening Processes

Data associated with 10,597 koala call-out records for the time period 1997 – 2017 were suitable for analysis. The numbers of annual call-outs peaked in 2000 and concordant with the overall koala reporting rate, have been decreasing progressively since that time (**Figure 3.11**). Part of this decrease is attributable to a lower number of 'sightings only' calls, where no action is recorded as being taken (**note:** no 'sightings-only' calls were evident in this dataset since 2010). The overall trend of decline may thus be in part reflective of changes in recording protocols, as well as a real decrease in the numbers of koala sightings and calls.

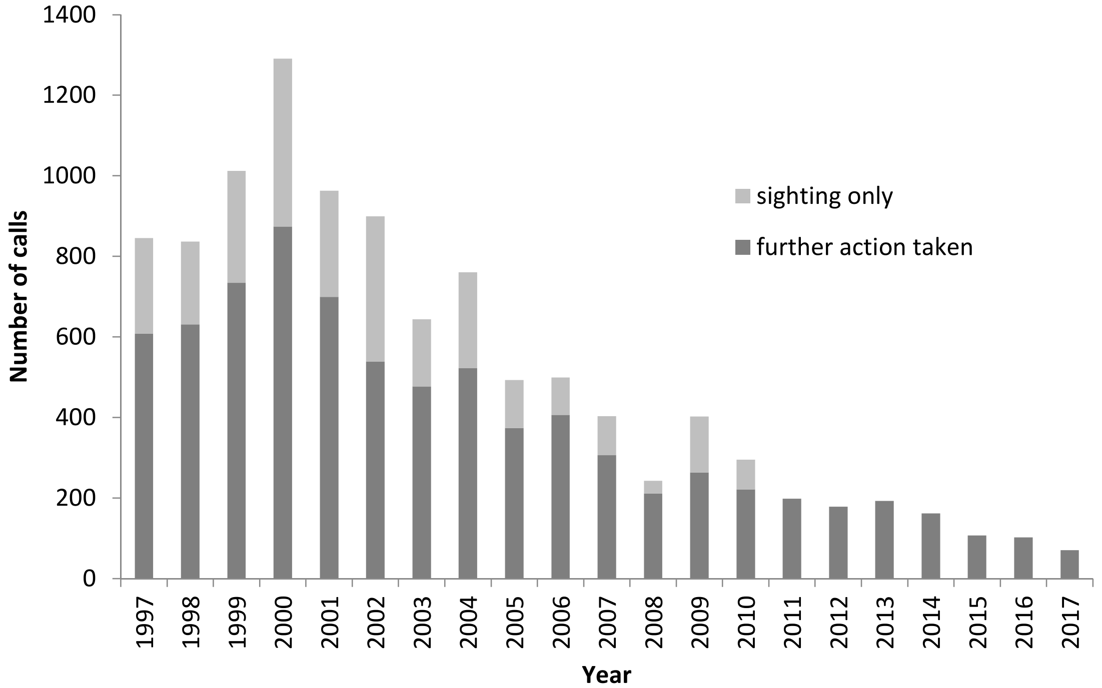



**Figure 3.11.** Annual numbers and response category of koala-calls collated by the Moggill Koala Hospital for the reporting period 1997 – 2017.

Excluding 2,722 'sightings only' calls, the most commonly attributable reasons associated with koala hospital call-outs were 'disease' (59.60%), 'vehicle-strike' (24.97%) and 'domestic dog attack' (8.41%) and 'other / unknown' (7.02%), the latter category including factors such as advanced age, falls, drowning, disorientation and other issues. These categories are also reflected in the predominant factors contributing to known koala mortalities across the Redlands Coast. Of the 4,853 known mortalities for the period 1997 – 2017, the most commonly attributed reasons were disease (56.77%), vehicle-strike (32.06%), domestic dog attack (8.14%) and other / unknown causes (3.03%). **Table 3.1** details the relationships between the reason for initial call-out and mortality causes.

**Table 3.1.** Principal reasons underpinning calls collated by Moggill Koala Hospital and associated causes of koala mortalities over the reporting period 1997 – 2017. Note that 'sightings only' calls are excluded from these data.

| Reason | No. call-outs | Causes of mortality |
|---|---|---|
| *Disease* | 59.60% (*n* = 4,714) | 56.77% (*n* = 2,725) |
| *Vehicle-strike* | 24.97% (*n* = 1,975) | 32.06% (*n* = 1,556) |
| *Dog Attack* | 8.41% (*n* = 665) | 8.14% (*n* = 395) |
| *Other / Unknown* | 7.02% (*n* = 555) | 3.03% (*n* = 147) |

Excluding the category of *Other/Unknown*, a breakdown of the data for the remaining categories of *Disease*, *Vehicle-strike* and *Dog attack* are as follows:

### *3.5.1 Disease*

Hospital rescue call records from 1997 - 2017 indicate that 4,714 diseased koalas were the subject of action by the koala hospital. Regression analyses show that the proportional representation of diseased koalas being reported over this time period has increased ($R^2$ = 0.8863) (**Figure 3.12**). Mann-Kendall trend tests demonstrate this trend to be statistically significant (Kendall's tau = 0.724, two-tailed $P$ < 0.001).

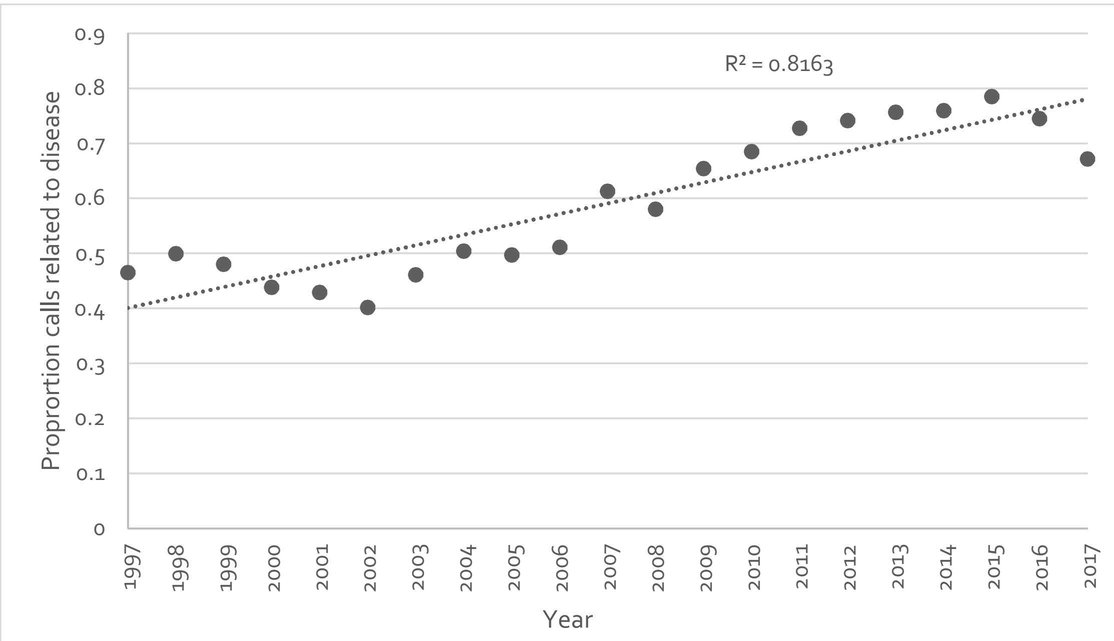



**Figure 3.12.** Proportional representation of koala call-outs over the period 1997 – 2017 that specifically relate to diseased koalas.

Of the 4,716 koalas that were presented with disease 2,757 are known to have subsequently died. This represents a mortality rate of 76.40% of diseased koalas for whom the outcome was recorded. Of koalas recorded as having died from disease, 83.13% (*n* = 2,292) were the result of a decision to euthanase the koala. Considering results for the period 1997 – 2017, and excluding years 2013 –

2015 due to anomalies in the recording protocols, the euthanasia trend over time has remained constant ($R^2$ = 0.008). Again excluding years 2013 – 2015, a Grubb's test for outliers reveals that while years 2011 and 2012 have the lowest euthanasia rates, they do not represent significant outliers ($P$ > 0.05) (**Figure 3.13**).

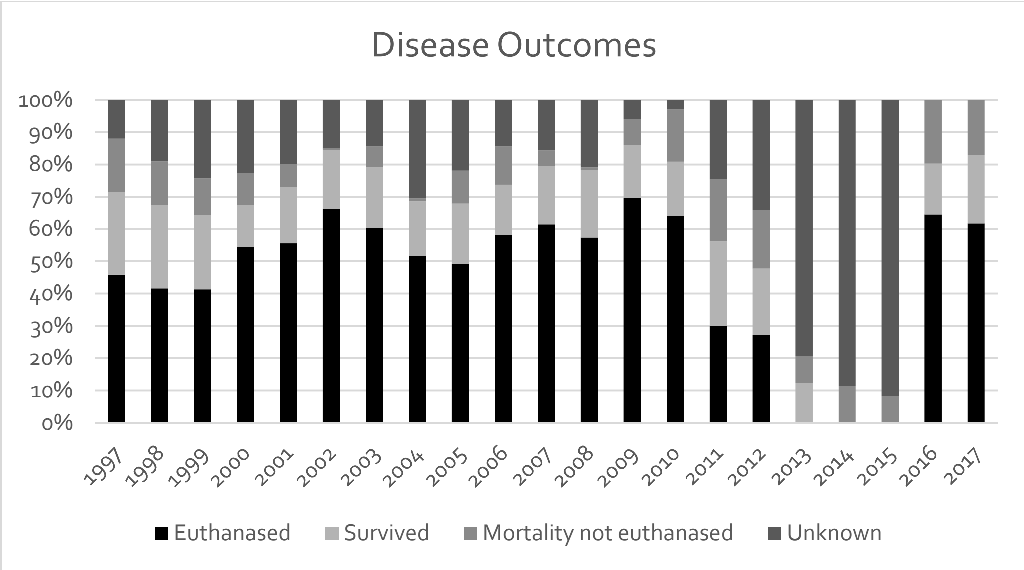



**Figure 3.13.** A one-hundred percent stacked column graph showing both disease frequencies and consequences over the period 1997-2017. The percentage of presented animals being euthanased are reflected in black, surviving animals in light grey, mortalities that were not euthanased in medium grey and disease incidences with unknown outcome in dark grey. The absence of euthansia data for 2013 – 2015 is due to anomalies in reporting protocols.

More females than males were reported as suffering from disease in general (female $n$ = 2,278; male $n$ = 1,995), though not significantly so. However, significantly more of the females that presented with symptoms of chlamydiosis (cystitis [$t$ = 2.07, $df$ = 23, $P$ < 0.01] and/or conjunctivitis [$t$ = 2.06, $df$ = 24, $P$ < 0.01]) were consequently euthanised, compared to males who presented with the same symptoms (**Table 3.2**).

Geographic trends in reported incidences of disease are illustrated in **Figure 3.14.** Disease records were highest and are mainly concentrated in the more urbanised northern half of the mainland Redlands Coast where observer density is greatest. Reported incidences of disease on NSI are also primarily restricted to areas of human habitation at Amity and Dunwich.

**Table 3.2.** Mean percentages of animals of both sexes euthanised annually across mainland Redlands Coast over the period 1997-2012 due to disease. (*) indicates the presence of a significant difference between males and females arising from a two-tailed *t*-test assuming unequal variance. Note that records on disease mortality become unreliable after 2012 and have subsequently been excluded from this analysis.

| | Mean percent of koalas euthanased ± SE | |
|---|---|---|
| | Female | Male |
| Cystitis | 61.31 ± 7.26 * (*n* = 981) | 32.43± 3.97 * (*n* = 503) |
| Conjunctivitis | 36.31 ± 3.63* (*n* = 581) | 23.81 ± 2.11 * (*n* = 381) |
| Wasted | 35.12 ± 4.50 (*n* = 562) | 27.75 ± 3.09 (*n* = 444) |

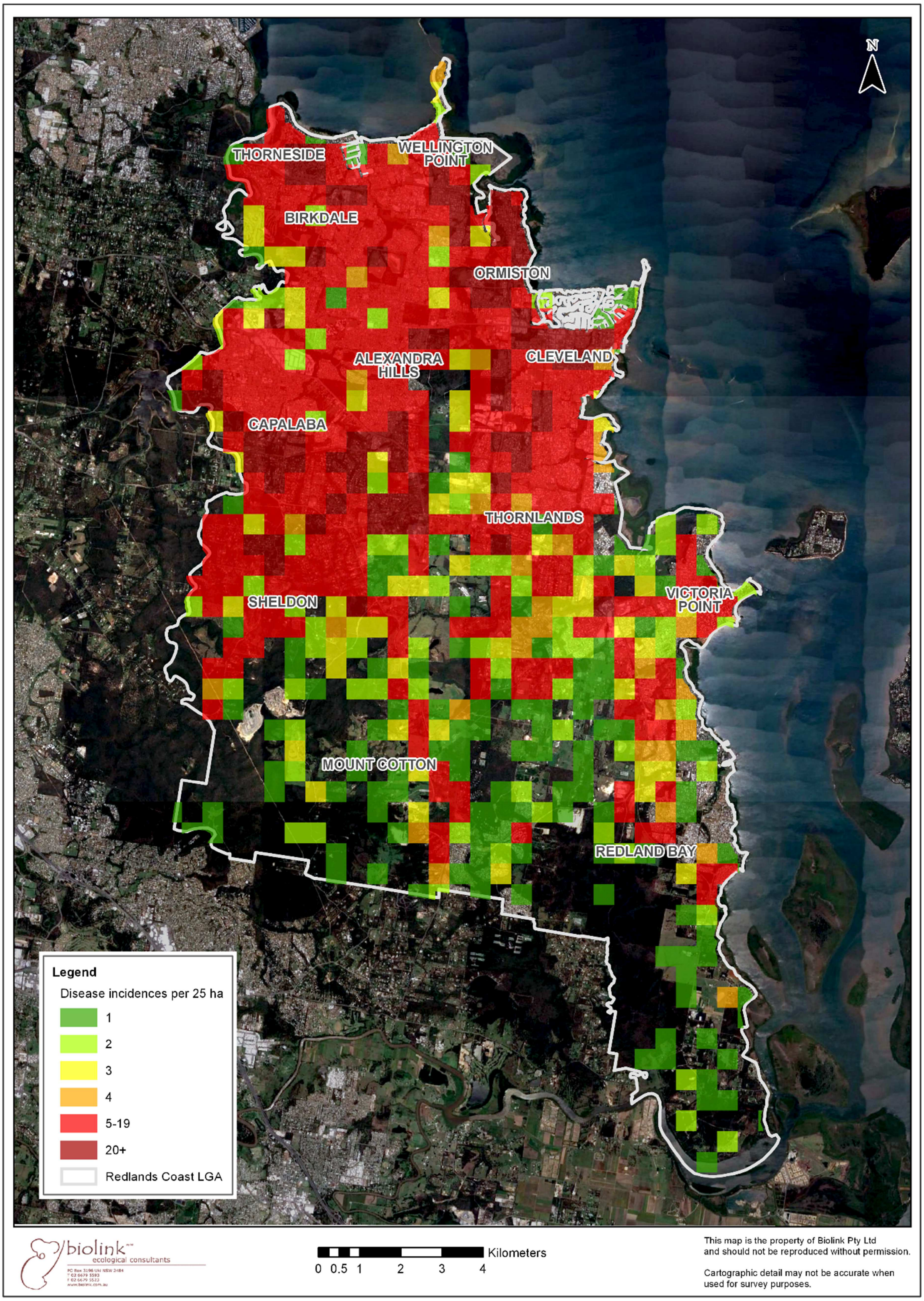



**Figure 3.14.** Frequency of reported incidences of disease on mainland areas of the Redlands Coast, here illustrated on a graduated basis with 500 m x 500 m (25 ha) grid-cells for the last three koala generations (2000-2017).

### *3.5.2 Vehicle-strike*

In common with disease, declining trends of vehicle-strike since 2000 reflect that of the koala reporting rate. Over the period 1997 – 2017 there were 1,975 call-outs related to vehicle-strikes where hospital action was taken, 78.78% of which (*n* = 1,556) resulted in the death of the koala (**Figure 3.15**). Of these mortalities, the largest proportion (45.11%, *n* = 702) were 'Dead On Arrival' (DOA) / 'other', the remainder either dying *post* admission (30.52%, *n* = 475) or being euthanised (24.36%, *n* = 379). Two-hundred and thirty-nine (12.11%) koalas struck by vehicles survived their injuries while 180 (9.11%) cases had unknown outcomes.

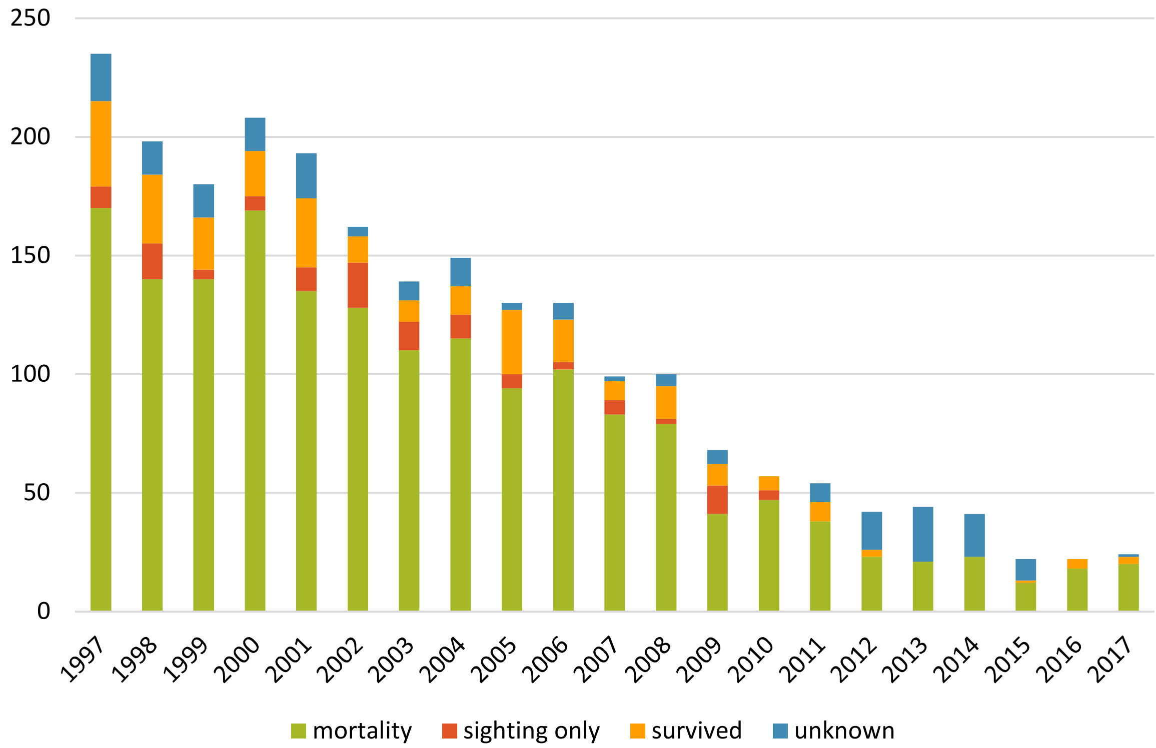



**Figure 3.15.** Frequency histogram of the reported numbers of koala vehicle-strike incidents over the period 1997 – 2017.

There was significant variation in the numbers of koalas being killed by vehicle-strike over the last three consecutive generations (Chi-square = 32.911, 2 *df*, $P < 0.001$). Counter-intuitively, there was a higher rate of koala deaths from vehicle-strike in the most recent koala generation (2012 - 2017), when compared to that of the previous two generations (2000 - 2011), when vehicle-strike deaths are considered as a proportion of all known koala mortalities. Of the individuals killed by vehicle strike, 36.15% (*n* = 411) were female and 59.01% (*n* = 671) were male. When partitioned and analysed by generation (**Figure 3.16**), significantly more male koalas are killed by vehicle-strike than are females (Chi-square = 124.95, 1 *df*, $P < 0.001$).

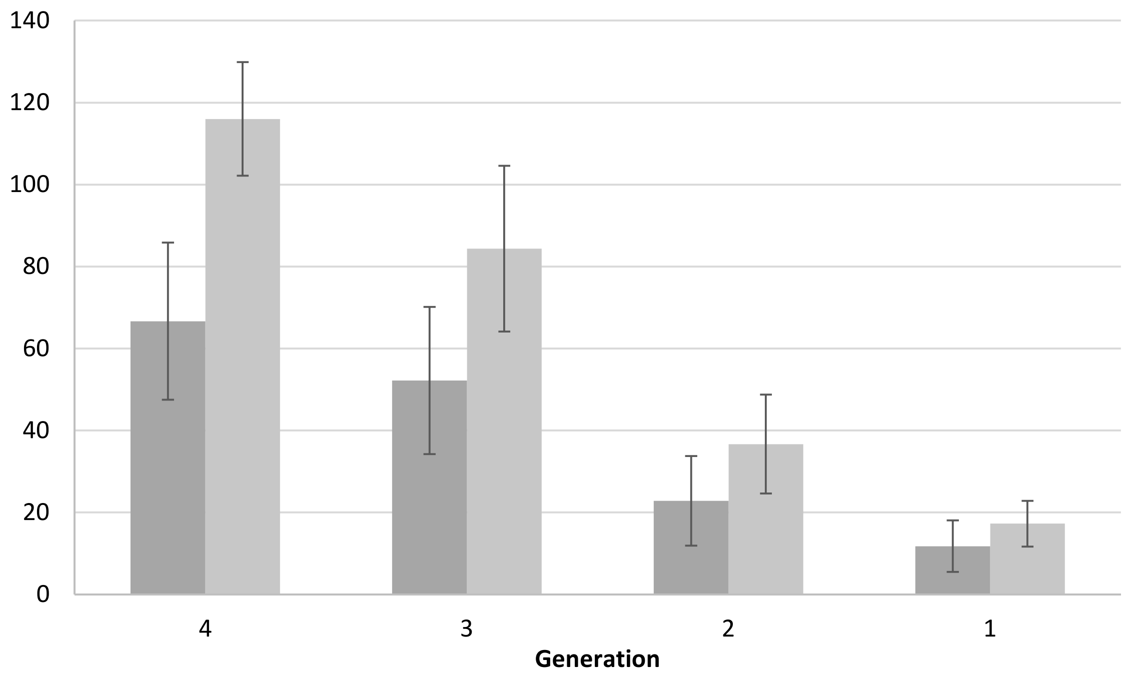



**Figure 3.16.** Generational gender-partitioned frequency histogram with the mean number of koalas involved in vehicle strikes from 1997 – 2017 with standard deviation error bars. Data for female koalas is reflected by the darker columns. Generation 1 = 2012 – 2017, Generation 2 = 2006 – 2011 and Generation 3 = 2000 – 2005.

Analysis of the most recent three koala generations of vehicle-strike data indicates areas of consistently high mortalities along

- Mt Cotton Road along its entirety from Capalaba to Mount Cotton
- Duncan Road, Capalaba through to the end of Boundary Road, Thornlands.
- Redland Bay Road, Capalaba
- Springacre Road through to Kingfisher Road, Thornlands (**Figure 3.17)**

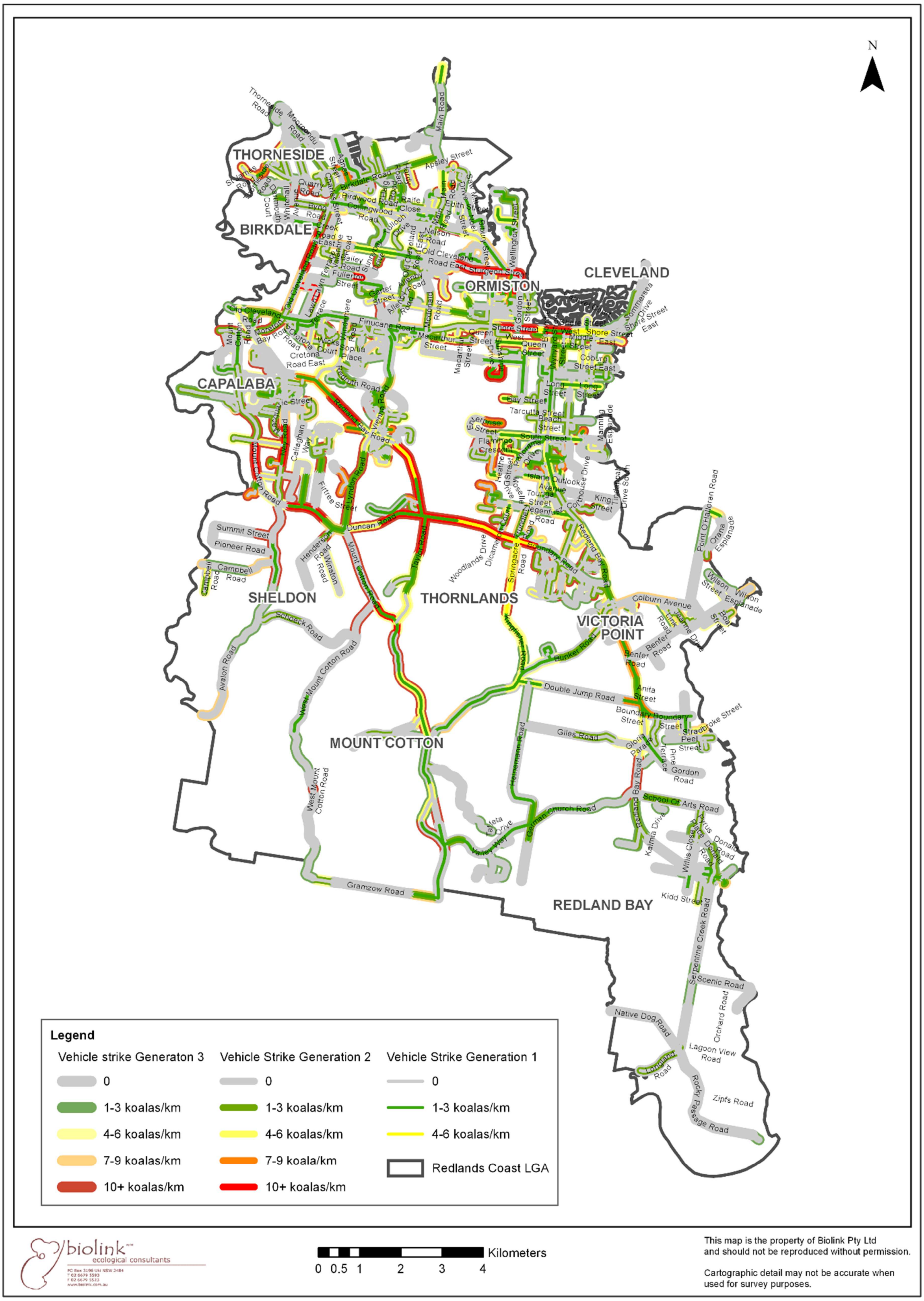



**Figure 3.17.** Road network showing koala road vehicle-strikes per km of road over three koala generations 2000 – 2017. The thickest line represents that of the koala generation 2000 – 2005, the previous generation 2006 – 2011 is a line of medium thickness and the most recent koala generation 2012 – 2017 is the thin central line superimposed on top.

Forty-two (42) vehicle-strikes pertained to koalas being hit by trains, 41 of which were known to have resulted in the death of the koala, with the remaining case having an unknown outcome. The majority of these deaths occurred in the period of 2000-2011, with only one animal recorded as hit by a train in 2014. Train-strikes were concentrated around Ormiston and Birkdale train stations and the overpass to the west of Wellington Point train station (**Figure 3.18**).


**Figure 3.18.** Locations of koalas known to have been killed by trains over the period 2000 – 2017 (*n* = 41). Coloured circles represent the generations of the koalas killed by trains with generation1 (red) = 2012 – 2017, generation 2 (yellow) = 2006 – 2011 and generation 3 (green) = 2000 – 2005.

### *3.5.3 Domestic Dog Attack*

Six hundred and sixty-five (665) dog attacks on koalas have resulted in hospital action since 1997 with 59.40% (*n* = 395) of these known to be fatal, 17.14% surviving their injuries (*n* = 114) and 23.46% (*n* = 156) having unknown outcomes. Of the fatalities where gender was known 46.8% (*n* = 193) were female and 50.48% (*n* = 208) were male. Least squares regression reveals a decreasing trend in the proportion of hospital admissions annually which are due to dog attack. ($R^2$ = 0.81, $F < 0.05$) (**Figure 3.19**).

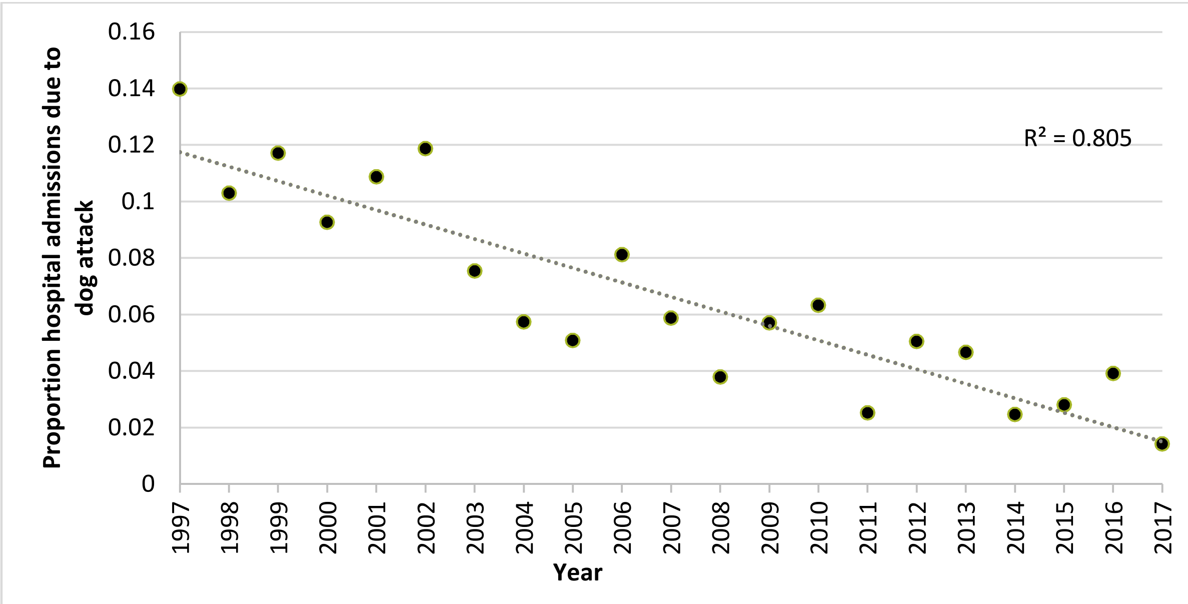



**Figure 3.19.** Proportional representation of annual hospital admissions due to dog attack over the period 1997 – 2017.

The geographical distribution of domestic dog attacks on the mainland shows densities of 4-5 dog attacks 25 $ha^{-1}$ around Thorneside, Ormiston and Capalaba (**Figure 3.20**). There are no high-density areas of dog attacks recorded south of Victoria Point. This trend is similar to that reported for disease where high density impacts appear to be correlated with more heavily urbanised areas. Dog attacks on NSI are reported infrequently, with three dog attacks 25 $ha^{-1}$ recorded at Dunwich and a single attack recorded at Amity for the period 2000 - 2017. No known dog attacks were recorded on NSI from 2012-2017.

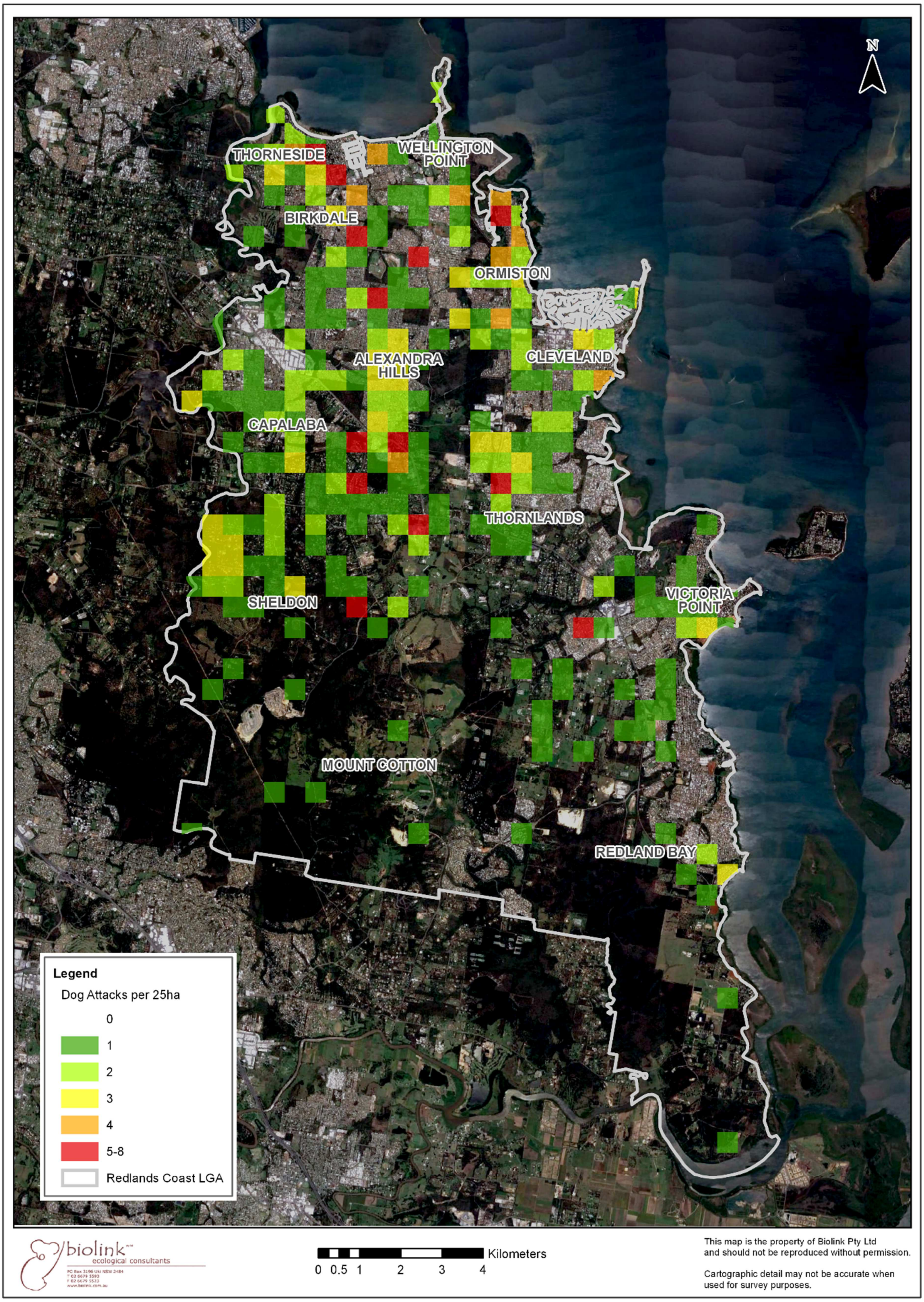



**Figure 3.20.** Frequency of reported incidences of attacks on koalas by domestic dogs from mainland areas of the Redlands Coast, here reflected on a graduated basis with 500 m x 500 m (25 ha) grid-cells for the last three koala generations (2000 - 2017).

## 3.6 Field Survey

Field survey assessments were undertaken on mainland areas of Redlands Coast from 22nd May – 25th July 2018, during which time 57 field sites were assessed, 39 of which contained one or more PKFTs. The distribution of surveyed field sites is illustrated in **Figure 3.21** with a summary of the associated survey data provided in **Appendix 1**. Evidence of koalas in the form of diagnostic faecal pellets was recorded at 27 of the 39 sampled field sites in which PKFTs were also recorded, the majority of which were located in the southwestern corner of the Redlands Coast (**Figure 3.21**). Amongst other things, this outcome translates to an overall habitat utilisation/occupancy estimate for koalas on mainland areas of Redlands Coast of 69.23% ± 14.49% (SE) of the available habitat; which is statistically indistinguishable from that of 70.81% estimated for the AoO by records analysis. One koala was recorded in the 23.86 ha of transect searches completed at these 39 sites to provide an indicative density estimate of 0.04 ± 0.03 (SE) koalas $ha^{-1}$ within areas of habitat that contain PKFTs.

Of the initial series of potential field sites that were identified for sampling on NSI, 36 were impacted by fire, 23 of which could be moved within the 100 m buffered area, while 13 were subsequently removed. Field survey assessments were undertaken from 16th July – 20th July 2018, during which time 40 field sites were assessed, of which only 8 contained PKFTs[5]. The distribution of surveyed field sites is illustrated in **Figure 3.22,** a summary of which is also provided in **Appendix 1**. Evidence of koalas in the form of diagnostic faecal pellets was recorded at all eight field sites in which PKFTs were also recorded. One koala was recorded in the 6.64 ha of transect searches to provide an indicative density estimate of 0.15 ± 0.12 (SE) koalas $ha^{-1}$.

A further three koalas were opportunistically observed during the course of the field survey program, all of which were noted to have extensive areas of white fur on the lower half of the body (cover photo refers).

[5] Initial survey design based on the potential presence of the PKFT *E. tereticornis* in RE 12.2.10.

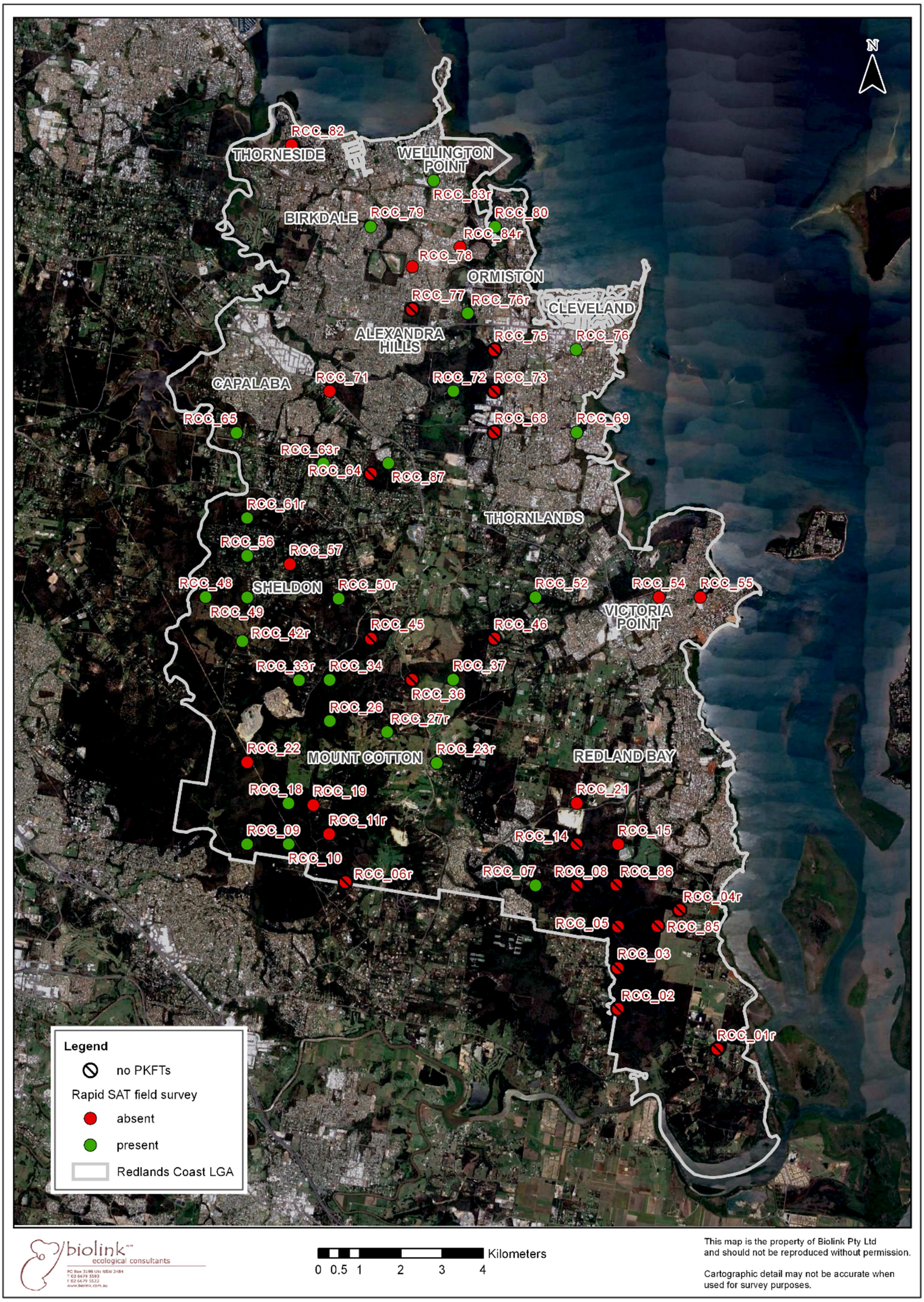



**Figure 3.21**. Locations of 57 sampled field sites across mainland Redlands Coast. Field sites that contained PKFTs and/or had evidence of utilisation by koalas is also illustrated (positive = green; negative = red). The majority of active sites were located in the southwestern corner of mainland Redlands Coast.

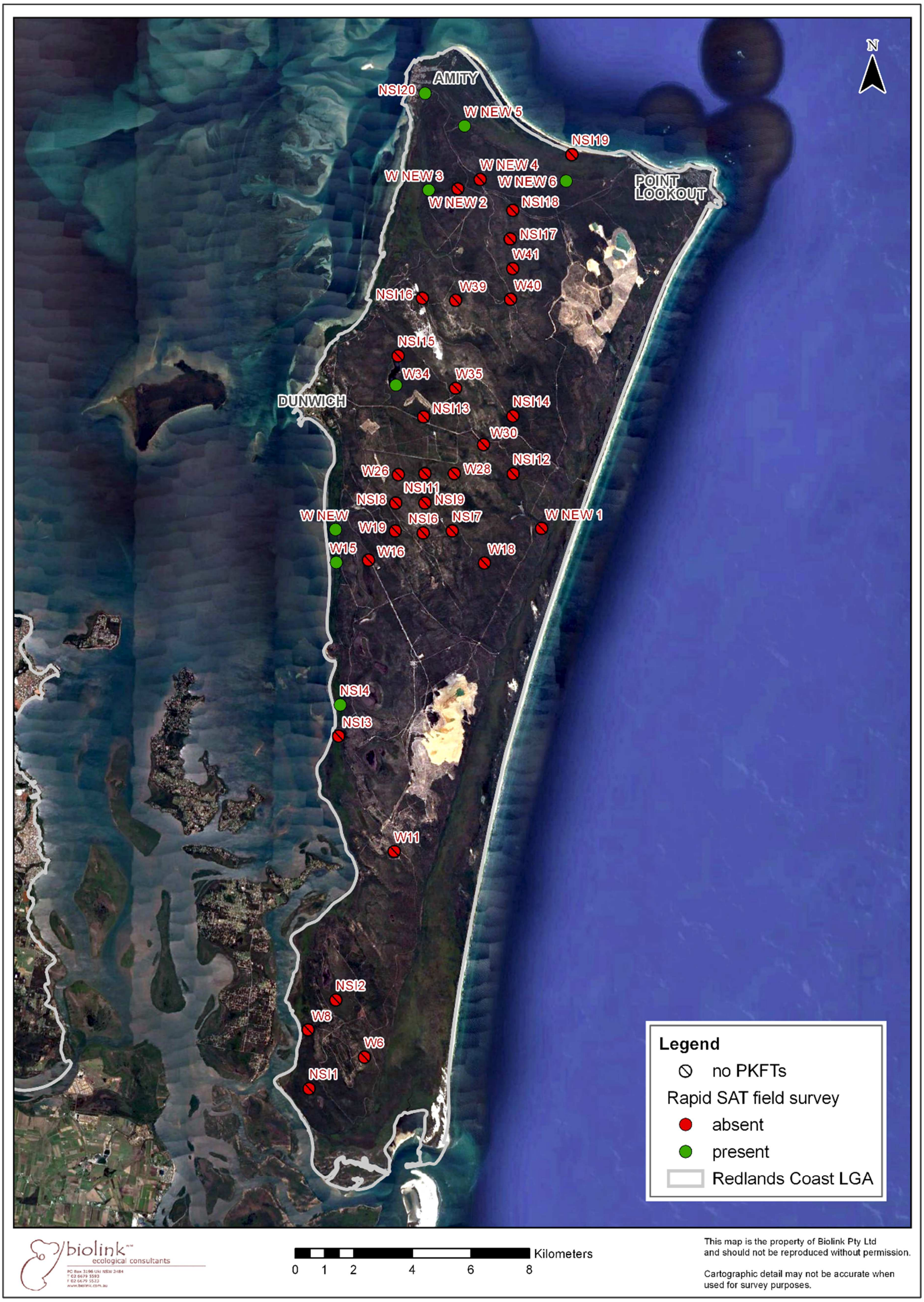



**Figure 3.22.** Locations of 40 sampled field sites across NSI. Field sites that contained PKFTs and/or had evidence of utilisation by koalas are also illustrated (positive = green; negative = red).

## 3.7 Regional Ecosystem mapping

### *3.7.1 Mainland*

Fifty-three[6] of the 57 sampled field sites allowed testing of conformity with the REDD and associated Technical descriptions. Scoring of these sites implied an overall accuracy estimate of 65.10 % ± 6.55% (SE) for current RE mapping layer across mainland Redlands Coast. A breakdown of the overall results in terms of conformity with the available RE mapping layer is provided in **Appendix 2**.

### *3.7.2 North Stradbroke Island*

Data relating to floristics and abundance of individual tree species in the tallest-stratum was collected from each of the 40 sampled field sites on NSI.

Thirty-six[7] of 40 sites allowed testing of conformity with existing REDD and associated Technical descriptions. Scoring of these sites enabled an accuracy estimate of 82.76 % ± 7.01 % (SE) to be derived. A breakdown of the overall results in terms of conformity with the available vegetation mapping layer is provided in **Appendix 2**.

## 3.8 Koala Habitat Classification

### *3.8.1 Mainland*

Based on a classification of the available RE mapping, the mainland portion of the Redlands Coast supports approximately 10,943 ha of vegetation cover, of which 8,346 ha qualifies as PKH by virtue of containing one or more of *E. robusta and/or E. tereticornis and/or E. microcorys and/or E. resinifera and/or grey gum and/or E. molucanna*). **Table 3.3** provides a breakdown of the koala habitat types while **Figure 3.23** illustrates the distribution of koala habitat types across mainland areas of Redlands Coast in terms of the twenty-two categories that have been identified. **Appendix 3** provides a summary of the associated koala habitat categorisations in terms of the available RE mapping for mainland areas of Redlands Coast.

**Table 3.3.** Koala habitat classifications and associated amount of corresponding preferred koala habitat occurring across mainland areas of Redlands Coast.

| Koala habitat type | Hectares |
|---|---|
| Secondary_A | 1963.913 |
| Secondary_A / Other | 132.268 |
| Secondary_A / Other / Secondary_C | 0.645 |
| Secondary_A / Secondary_B | 0.638 |

[6] Fours sites were located in parklands
[7] Four sites were located in non-remnant vegetation

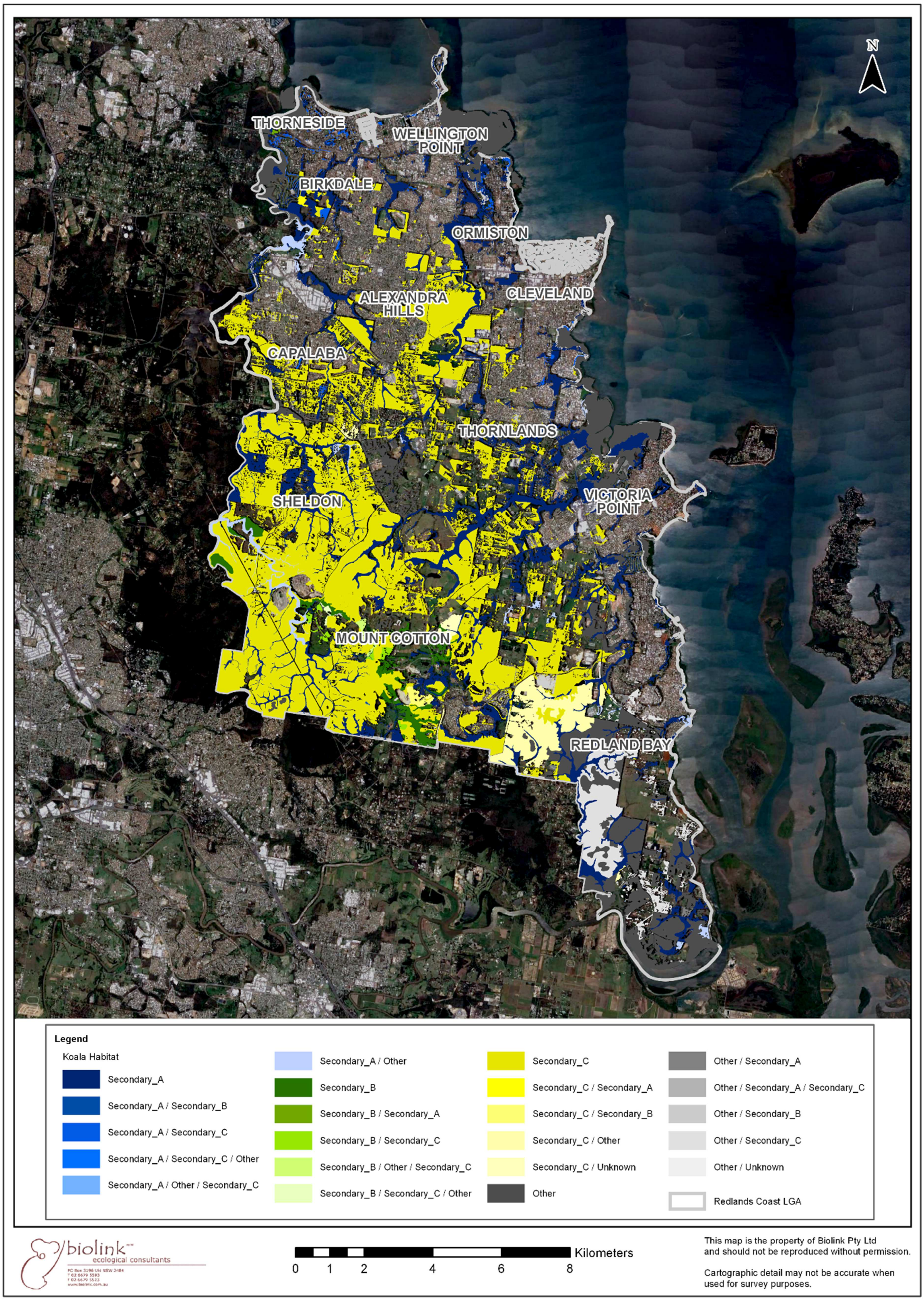
| | |
|---|---|
| Secondary_A / Secondary_C | 69.012 |
| Secondary_A / Secondary_C / Other | 0.841 |
| Secondary_A / Unknown | 0.096 |
| Secondary_B | 188.605 |
| Secondary_B / Other / Secondary_C | 20.189 |
| Secondary_B / Secondary_A | 3.454 |
| Secondary_B / Secondary_C | 31.665 |
| Secondary_B / Secondary_C / Other | 5.274 |
| Secondary_C | 5051.731 |
| Secondary_C / Other | 385.962 |
| Secondary_C / Secondary_A | 17.422 |
| Secondary_C / Secondary_B | 24.081 |
| Secondary_C / Unknown | 28.801 |
| Other | 1438.772 |
| Other / Secondary_A | 26.295 |
| Other / Secondary_A / Secondary_C | 0.421 |
| Other / Secondary_A / Unknown | 0.074 |
| Other / Secondary_B | 3.026 |
| Other / Secondary_C | 391.641 |
| Other / Unknown | 0.256 |
| Unknown | 0.144 |

### *3.8.2 North Stradbroke Island*

NSI supports approximately 26,976 ha of vegetation cover, of which 2,726 ha qualifies as PKH by virtue of containing one or more individuals of *E. robusta* and/or *E. tereticornis* and/or *E. resinifera.* **Table 3.4** provides a breakdown of PKH across NSI in terms of the two habitat categories that can be identified, while the overall distribution is illustrated in **Figure 3.24.**

**Table 3.4.** Koala habitat classifications and associated amount of corresponding preferred koala habitat occurring across North Stradbroke Island.

| Koala habitat type | Hectares |
|---|---|
| Secondary_A | 2,712.4 |
| Other/Secondary_A | 13.4 |
| Other | 17,128.9 |



N
THORNESIDE
WELLINGTON POINT
BIRKDALE
ORMISTON
CLEVELAND
ALEXANDRA HILLS
CAPALABA
THORNLANDS
VICTORIA POINT
SHELDON
MOUNT COTTON
REDLAND BAY
Legend
Koala Habitat
Secondary_A
Secondary_A / Secondary_B
Secondary_A / Secondary_C
Secondary_A / Secondary_C / Other
Secondary_A / Other / Secondary_C
Secondary_A / Other
Secondary_B
Secondary_B / Secondary_A
Secondary_B / Secondary_C
Secondary_B / Other / Secondary_C
Secondary_B / Secondary_C / Other
Secondary_C
Secondary_C / Secondary_A
Secondary_C / Secondary_B
Secondary_C / Other
Secondary_C / Unknown
Other
Other / Secondary_A
Other / Secondary_A / Secondary_C
Other / Secondary_B
Other / Secondary_C
Other / Unknown
Redlands Coast LGA
biolink ecological consultants
0 1 2 4 6 8 Kilometers
This map is the property of Biolink Pty Ltd and should not be reproduced without permission.
Cartographic detail may not be accurate when used for survey purposes.

**Figure 3.23.** Distribution and categories of remaining areas of Preferred Koala Habitat on mainland Redlands Coast based on current Regional Ecosystem mapping.

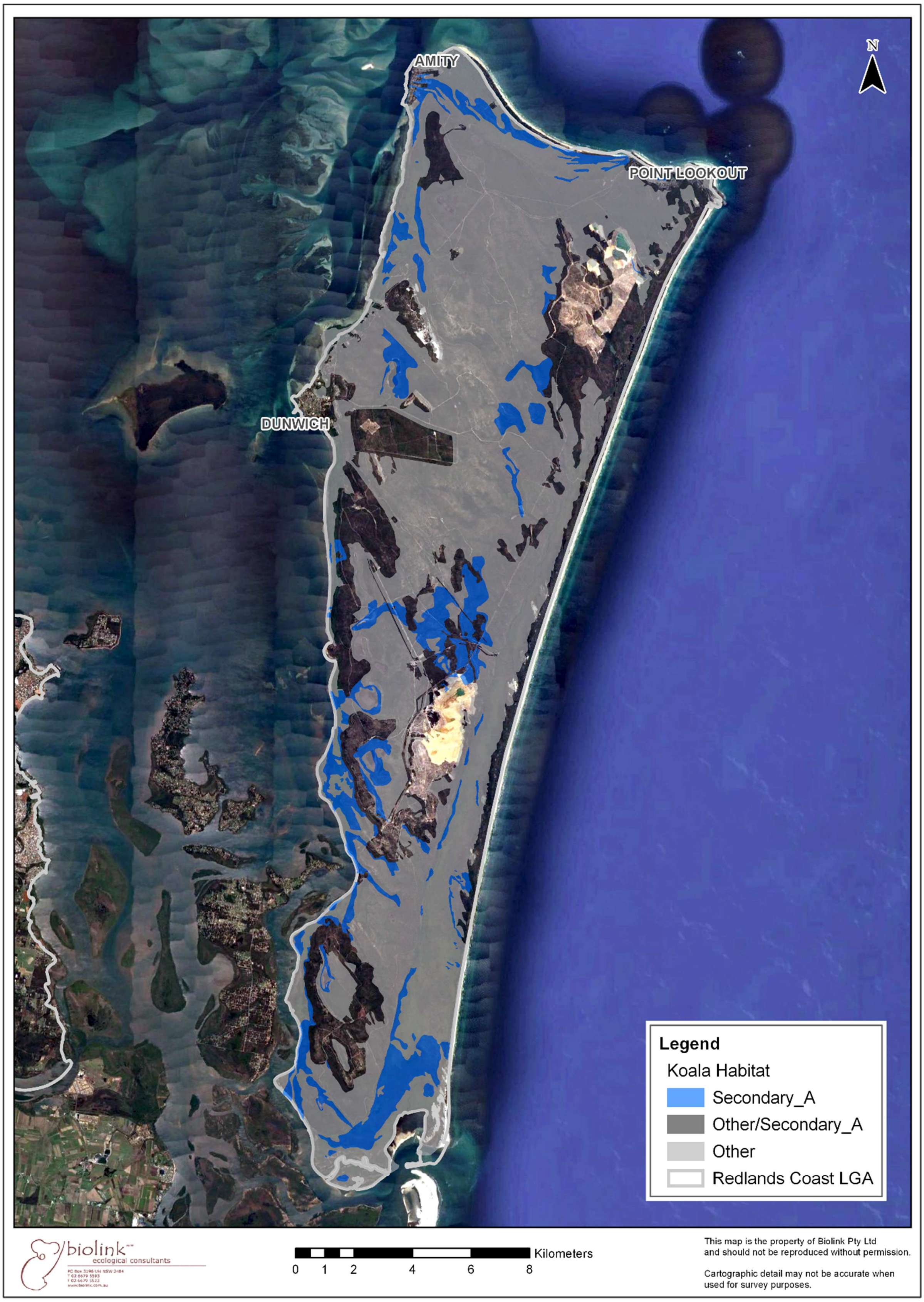


**Figure 3.24.** Distribution and categories of remaining areas of preferred koala habitat on North Stradbroke Island based on current Regional Ecosystem mapping.

## 3.9 Koala Population Size

### *3.9.1 Mainland*

A density of 0.04 ± 0.03 (SE) koalas $ha^{-1}$ when extrapolated across the 8,346 ha of PKH remaining on the mainland portion of the LGA results in a koala population size estimate for mainland Redlands Coast of 334 koalas, the greater proportion of which given the distribution of active sites (Figure 3.21 refers), will be located in the southwestern corner of the LGA.

A density estimate modified to reflect that only areas being actively utilised by koalas were searched via transects *(i.e.* 0.063 koalas $ha^{-1}$ derived from only those sites in which evidence of koalas in the form of diagnostic faecal pellets was detected), multiplied by the associated amount of PKH estimated by field survey to be occupied (8,346 x 0.69 ± 0.14 (95% CI) results in a more statistically refined but similarly small koala population size estimate for mainland Redlands Coast of 345 ± 74 (95% CI) koalas.

### *3.9.2 North Stradbroke Island*

The density estimate of 0.15 ± 0.12 (SE) koalas $ha^{-1}$ when extrapolated across the 2,726 ha of PKH estimated to be present on NSI results in a koala population size estimate of 409 koalas.

# 4. Discussion

The outcomes arising from this report reflect the first systematic assessment of koala distribution and abundance of koalas across the Redlands Coast LGA, historical records dating to 1943 indicating that the species has a long history of occupation. Available evidence based on sightings and hospital admissions as detailed herein, in addition to results arising from previous surveys for mainland areas of the Redlands Coast (DERM, 2008) indicate that the koala population numbered in the thousands as recently as a decade ago, but now numbers less than 400 individuals. Given that neither of the two key range parameters *EoO* or *AoO* across mainland areas of Redlands Coast has changed significantly over time and that the field survey has independently validated the records-based AoO estimate of approximately 70.81% of available habitat, it can be confirmed that it is not the overall distribution of the population that has changed but the density of animals across the landscape. This outcome is at odds with current paradigms of decline which require a reduction in the AoO as a measure of endangerment (IUCN 1994). Indeed, the listing of the koala as a threatened species by the Commonwealth (DSEP&C 2010) was predicated on such a documented reduction in range, as are other State-based and/or regional listings. The contrasting outcome provided by the data for mainland areas of Redlands Coast thus points to another factor driving the reduction in koala density.

The outcomes in the preceding paragraph are of interest from a number of perspectives, not the least of which is that the rapid reduction in population size has occurred within the last three koala generations. While some aspects of the decline in density may in part reflect cyclical trends and a natural regulation of koala numbers, it appears to be most strongly associated with the implementation of disease management protocols more so than other issues such as vehicle-strike and domestic dog attack. The preceding statement is evidenced by the fact that more than 2000 koalas have been euthanised over the time period 2000 - 2017; a number which when considered in terms of the average numbers of koalas being removed from the population each year (*n* = 160), far exceeds the minimum value of approximately 3% of total population size annually that has been independently identified by Population Viability Analysis programs such as Vortex[8] as sufficient to initiate and drive koala population decline (Phillips *et al.* 2006; Phillips *et al*. 2015).

Mainland areas of the Redlands Coast LGA supports approximately 10,943 ha of vegetation cover, of which 8,346 ha qualify as Preferred Koala Habitat by virtue of containing one or more PKFTs, whilst on NSI approximately 26,976 ha of vegetation cover remains, of which 2,726 ha is Preferred Koala Habitat for the same reason. Examination of conformity with RE mapping and floristic data obtained from field sites indicated a low accuracy for mainland Redlands Coast relative to that for NSI. The extent to which this influences the total extent of PKH is unknown however because while the RE coding that applies to a given polygon may be incorrect, when corrected the appropriate coding may also contain PKFTs in which case the amount of PKH changes little. Additionally, the results that have been obtained cannot be generically extrapolated across all affected REs, the changes can only be applied to the individual polygons that were assessed during the course of the field survey program.

Disease-mediated mortalities in free-ranging koala populations are symptomatic not causal (McAlpine 2017) and there are now several population profiling studies that evidence the capacity of free-ranging koala populations to maintain viable population levels and arguably optimal reproductive rates in the presence of disease (*e.g*. Phillips and Forsman 2005; Biolink 2007; Phillips *et al.* 2015; Biolink 2017). Importantly, available records for mainland areas of the Redlands Coast further evidence that the removal and euthanasia of diseased koalas has not been effective in decreasing the proportion of diseased koalas in the population. Selective culling in Tasmanian devils has also been demonstrated to neither reduce the rate of disease progression nor reduce population level impacts of disease (Lachish *et al*., 2010). As discussed in more general terms by Peron (2013) and while well intentioned, adherence to a policy that advocates the euthanasia of diseased koalas from within a population is not just poorly informed / naïve but is also ecologically irresponsible for at least the following reasons:

[8] Lacy, R.C., and J.P. Pollak. 2014. *Vortex: A stochastic simulation of the extinction process. Version 10.0*. Chicago Zoological Society, Brookfield, Illinois, USA.Chicago Zoological Society 2014.

1. Euthanasia imposes an unnecessary and dangerous selection pressure on what is increasingly being recognised as a dynamic immunological relationship that only becomes dysfunctional in the presence of anthropogenic disturbance,
2. Euthanasia results in the loss of koalas from the broader population and so has the potential to facilitate social dissolution, a diminishment of reproductive output and associated population decline (see also Tuyttens *et al*. 2000 and McDonald *et al*. 2008), and
3. Euthanasia results in the loss of alleles / genetic diversity that may impart hitherto unknown benefits to the population as a whole (McAlpine *et al*., 2017).

In contrast to the situation on mainland areas of Redlands Coast, the NSI koala population appears to be relatively stable and indeed, expanding its distribution across the island. In addition to the increased EoO estimated by records analysis, this assertion is further evidenced by the concurrently undertaken study by Cristescu *et al*. (2018) which, for the first time, recorded signs of habitat utilisation / occupancy by koalas in the south-eastern corner of NSI. This is new knowledge that will result in a further expansion of the NSI koala EoO when records are next reviewed; it is also a positive outcome and so presents an opportunity to learn and gain insight into the nuances of koala conservation biology and population management. As detailed in the work by Cristescu *et al*. (2011) the NSI population has a long period of residency and in common with other populations such as we have alluded to in the preceding paragraph, clearly manages to maintain optimal occupancy rates and positive population growth in the presence of disease, vehicle-strike and domestic dog attack, as well as periodic large-scale fire events. In considering the history of the NSI koala dynamic we see a population that has thus far demonstrably withstood the test of time and maintained viability with relatively little human intervention, not because of it (Harris *et al*., 2002). Given this circumstance and that of the genetic knowledge obtained by Cristescu *et al*. (2018), we concur that inbreeding appears as the most likely primary longer-term management consideration given that the major influence on maintenance of koala genetic diversity on NSI – fire, its causes, consequences and management – invariably involves a strong anthropogenic element. Hence, we forecast that assessment and monitoring of the koala gene pool on NSI may identify the need for carefully screened genetic supplementation over time in order to avoid issues associated with progressive and cumulative bottlenecking effects and associated small population paradigms as recently discussed by Phillips (2018).

Field survey outcomes have confirmed that a disproportionately large area of occupied habitat is located in the south-western corner of the mainland area of Redlands Coast. This area, which is part of a larger habitat area in the adjoining Logan City LGA mostly comprises low carrying capacity habitat and so supports a naturally occurring, low density koala population. It is our assertion that collectively, this large habitat area likely functions as the ‘engine room’ for koalas in the mainland areas of the Redland Coast and associated LGAs and thus warrants recognition as a regionally significant source population. If the mainland Redlands Coast koala population is to be recovered to more sustainable density levels (*i.e*. a 5 - 6-fold increase from current density estimates), it is mostly from this area that the majority of animals will be recruited from. In order to facilitate this, two actions will be required of Council, the first of which will be to decrease the vehicle-strike potential at key locations likely to be traversed by koalas dispersing from this area, the second to optimise colonisation potential by minimising disturbance to the remaining habitat areas being occupied by this key population.

# 5. Recommendations

For the purpose of this report we have limited our recommendations to four primary undertakings, all of which are considered to be of equal importance in terms of reversing the current trend of reducing koala density / population decline and so securing a future for mainland Redlands Coast koalas. Moreover, if these recommendations are not implemented as soon as is practicably possible, we foresee ongoing reductions in koala density across mainland Redlands Coast, the extent of which if causal factors continue to operate could be responsible for localised extinction of the mainland Redlands Coast koalas within the next 2 - 3 koala generations. Our four key recommendations are as follows:

*1. Establishment of a long-term monitoring program*

Future monitoring and reporting of changes in the occupancy status of PKH areas being utilised by mainland Redlands Coast and NSI koalas will be best informed by creation of permanent monitoring points located in areas of PKH across the LGA. Sampling protocols would record koala presence / absence at some or all of these sampling points at a given sampling event, as well as (if required) the application of direct count methodologies – ideally transects – so as to also be able to detect changes in density and so detect any changes in koala population size.

We propose that Council commence the task of consolidating a long-term monitoring program for the Redlands Coast koalas. On both the mainland and on NSI this can be initiated by progressively securing access to sites, the locations of which are guided by the 500 m point-based grid intersect overlays '*Monitoring_sites_mainland*' and '*Monitoring_Sites_NSI*' that have been created as an output from this project. The mainland has 80 primary sites at 1 km intersections and 89 ancillary sites at 500 m intersections. The one kilometre grid is only placed in the south-west corner of the LGA. Thirty-eight of these sites were completed as part of the field assessment in this report. North Stradbroke Island monitoring grid has 88 permanent monitoring sites, with five of these completed during the field assessment addressed by this report.

In order for a proposed sampling point on the grids for both mainland areas of Redlands Coast and on NSI to be deemed suitable for long-term monitoring the following criteria must be met:

a) Have appropriate permissions in place to enable regular access and assessment, and
b) Contain 5 – 7 PKFTs > 300 mm dbh in close proximity to the sampling coordinates.

Ideally, the monitoring point should be permanently identified to ensure that exactly the same area is being re-sampled at any future monitoring event. The baseline sampling tool will be Rapid-SAT (following paragraph refers) ± designated area for direct count transect searches.

Ideally, all sites comprising the permanent monitoring grid should be sampled once in a given koala generation, the minimum data set comprising koala presence/absence data determined by the presence/absence of koala faecal pellets within a 1 m radius from the base of the 5 – 7 PKFTs being sampled at each site. The Rapid-SAT approach is predicated by knowledge that in areas being utilised by koalas, there is a 50% probability of faecal pellets occurring within 1 m of the base of any PKFT ≥ 300 mm diameter at breast height (DBH) (Phillips and Wallis 2016). For the purpose of occupancy monitoring, the Rapid-SAT assessment process stops as soon as the first faecal pellet is detected (in which case koalas are deemed to be present), or the 5 – 7 PKFTs closest to the site coordinates have been inspected (in which case koalas are deemed to be absent with a measure of 95% (5 trees) or 99% (7 trees) confidence respectively, whichever happens first.

There is potential for this monitoring program to become a citizen science engagement with koala conservation.

*2. Review of procedures informing decisions to euthanise koalas*

As discussed elsewhere in this report, we are of the opinion that the removal of koalas deemed to be diseased and/or non-reproductive and the subsequent euthanising of these animals has been the primary contributing factor to the current reduction in koala density / population size across mainland areas of the Redlands Coast. Importantly, the analyses of hospital data undertaken by this study have provided no evidence that implementation of this policy has in any way been effective in either decreasing the proportion of diseased koalas in the population and/or increasing the proportion of healthy koalas in the population.

The situation in terms of current decision-paths informing the decision to euthanise are complex, experiential and poorly informed. While some authorities maintain that infertile koalas should be euthanased (DES 1992, QPWS 2002), methods for determining infertility (Loader 2010, QPWS 2002) disagree with the findings of Obendorf (1981) and others (Legione 2016). At some institutions koalas with a body score of lower than seven are considered likely candidates for euthanasia (Loader, 2010) while a body score of seven is common and not typically considered of concern in both captive and wild koalas. Koalas have recovered from body scores as low as five following appropriate husbandry protocols (P. O'Callaghan pers. com). Field observations of multiple 'healthy' koalas across populations at demographic equilibrium often record body scores lower than seven (S. Phillips, unpub. data). Also in Queensland, koalas of 6 - 7 years of age are considered to be sufficiently aged as to have tooth wear that deem it unlikely to survive in the wild (and hence a candidate for euthanasia), yet koalas assessed with tooth wear indicating an age greater than ten have been successfully released back into the wild and survived (C. Flanagan, Clinical Director, Port Macquarie Koala Hospital, pers comm.).

Given this circumstance we propose that Council seek Government support for a review of standards that currently inform decisions resulting in the euthanasia of ‘diseased’ koalas, the intent of which is to ensure that greater numbers of koalas are effectively returned to the wild unless the animal satisfies each of the following four criteria:

a) A Body Condition Score < 5 and
b) An adult body weight of < 5 kg and
c) Is clearly expressing symptoms of chronic chlamydiosis[9] in the form of conjunctivitis / cystitis and/or
d) Displaying toothwear that is consistent with an animal that is greater than 13 years of age (Gordon, 1991), or
e) Is otherwise moribund[10] and deemed unlikely to respond to antibiotic therapy by a qualified veterinarian or other person with clinical koala management experience.

[9] Inflamed conjunctiva +/- loss of vision and corneal opacity / stained rump +/- urinary incontinence / discharge

[10] Moribund is defined as not eating, drinking or moving for two days (Wilkinson, 1996) and uses Clearview chylymidia antigen chlaymidia kit as recommended by Wood and Timms (1992)

Given that euthanasia protocols appear at odds with ecological knowledge and observations and with a view to assisting any review process we have developed a draft triage flowchart (**Figure 5.1**).

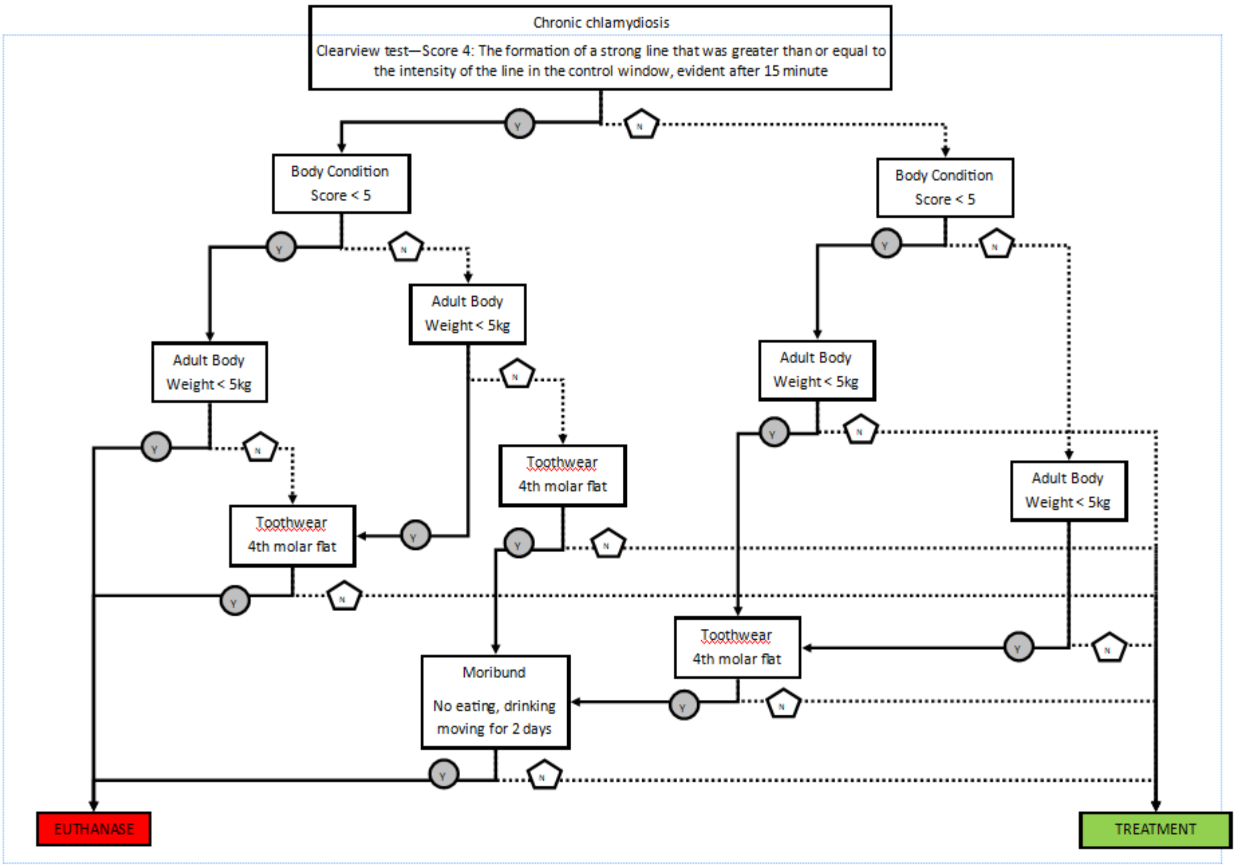



**Figure 5.1** Proposed triage flowchart of euthanasia protocols.

3. *Reducing the potential for vehicle-strike*

Records analyses have demonstrated that koala mortalities arising from vehicle-strike are a primary and ongoing risk to longer-term survival of koalas across mainland areas of the Redlands Coast. Moreover, even in the face of a clear decline trend over the period 2000 – 2017, it is demonstrable that there has been both a significant increase in the rates of koalas being killed by vehicle-strike in the last koala generation, and also that koalas are entering the road corridor and being killed in areas that have been fenced in an attempt to restrict access. More so than disease and/or domestic dog attack (which remains on ongoing matter of community engagement), koala mortalities arising from vehicle-strike is arguably the only anthropogenic impact that can be successfully mitigated if there is a will to do so.

We recommend the following actions be implemented immediately:

a) Council should plan to develop a koala vehicle-strike mitigation strategy that amongst other things proposes a timeline to implement best-practice mitigation measures at each of the key vehicle-strike locations identified on page 38 of this report

*4. Development of a strategic development control plan*

In collaboration with Logan City counterparts, Council should work to draft a Strategic Development Control Plan intended to guide development outcomes in the northwest of the Logan City LGA and southwest of the RCC LGA respectively such that further fragmentation of areas of preferred koala habitat is avoided, connectivity is maximised and measures to mitigate threatening processes such as vehicle-strike and domestic dog attack are embedded in planning outcomes.

## Acknowledgements

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# Appendix 1 – Field survey data

Mainland Redlands Coast

| Site ID | PKFTs present | Easting | Northing | Koala evidence |
|---|---|---|---|---|
| RCC_01r | | 530340 | 6937968 | × |
| RCC_02 | | 527927 | 6938943 | × |
| RCC_03 | | 527923 | 6939938 | × |
| RCC_04r | | 529424 | 6941348 | × |
| RCC_05 | | 527928 | 6940939 | × |
| RCC_06r | | 521310 | 6942020 | × |
| RCC_07 | *E. robusta* | 525926 | 6941941 | ✓ |
| RCC_08 | | 526930 | 6941938 | × |
| RCC_09 | *E. microcorys, E. resinifera* | 518925 | 6942941 | ✓ |
| RCC_10 | *E. microcorys, E. resinifera* | 519933 | 6942944 | ✓ |
| RCC_11r | *E. resinifera* | 520916 | 6943190 | × |
| RCC_14 | | 526926 | 6942944 | × |
| RCC_15 | *E. microcorys* | 527932 | 6942940 | × |
| RCC_18 | *E. microcorys* | 519929 | 6943937 | ✓ |
| RCC_19 | *E. moluccana* | 520533 | 6943894 | × |
| RCC_21 | *E. microcorys* | 526927 | 6943940 | × |
| RCC_22 | *E. microcorys* | 518928 | 6944940 | × |
| RCC_23r | *E. tereticornis* | 523527 | 6944921 | ✓ |
| RCC_26 | *E. propinqua* | 520933 | 6945937 | ✓ |
| RCC_27r | *E. propinqua* | 522323 | 6945670 | ✓ |
| RCC_33r | *E. microcorys, E. propinqua* | 520185 | 6946929 | ✓ |
| RCC_34 | *E. propinqua* | 520928 | 6946937 | ✓ |
| RCC_36 | | 522927 | 6946940 | × |
| RCC_37 | *E. microcorys* | 523927 | 6946942 | ✓ |
| RCC_42r | *E. propinqua* | 518811 | 6947881 | ✓ |
| RCC_45 | | 521931 | 6947941 | × |
| RCC_46 | | 524928 | 6947944 | × |
| RCC_48 | *E. microcorys* | 517918 | 6948944 | ✓ |
| RCC_49 | *E. propinqua* | 518929 | 6948936 | ✓ |
| RCC_50r | *E. microcorys* | 521149 | 6948906 | ✓ |
| RCC_52 | *E. microcorys* | 525926 | 6948939 | ✓ |
| RCC_54 | *E. tereticornis* | 528922 | 6948940 | × |

| | | | | |
|---|---|---|---|---|
| RCC_55 | *E. tereticornis* | 529925 | 6948944 | × |
| RCC_56 | *E. propinqua* | 518928 | 6949949 | ✓ |
| RCC_57 | *E. propinqua* | 519963 | 6949747 | × |
| RCC_61r | *E. propinqua* | 518925 | 6950867 | ✓ |
| RCC_63r | *E. microcorys, E. resinifera* | 520775 | 6952183 | ✓ |
| RCC_64 | | 521929 | 6951939 | × |
| RCC_65 | *E. tereticornis* | 518668 | 6952934 | ✓ |
| RCC_68 | | 524927 | 6952946 | × |
| RCC_69 | *E. tereticornis* | 526926 | 6952945 | ✓ |
| RCC_71 | *E. microcorys* | 520929 | 6953940 | × |
| RCC_72 | *E. resinifera* | 523934 | 6953943 | ✓ |
| RCC_73 | | 524928 | 6953939 | × |
| RCC_75 | | 524930 | 6954942 | × |
| RCC_76 | *E. microcorys* | 526913 | 6954952 | ✓ |
| RCC_76r | *E. tereticornis* | 524280 | 6955839 | ✓ |
| RCC_77 | | 522929 | 6955933 | × |
| RCC_78 | *E. tereticornis* | 522935 | 6956963 | × |
| RCC_79 | *E. microcorys* | 521923 | 6957942 | ✓ |
| RCC_80 | *E. tereticornis* | 524946 | 6957936 | ✓ |
| RCC_82 | *E. tereticornis* | 520004 | 6959923 | × |
| RCC_83r | *E. tereticornis* | 523454 | 6959067 | ✓ |
| RCC_84r | *E. tereticornis* | 524096 | 6957447 | × |
| RCC_85 | | 528887 | 6940952 | × |
| RCC_86 | | 527890 | 6941956 | × |
| RCC_87 | *E. microcorys* | 522355 | 6952193 | ✓ |

NSI Field Survey Data

| Site ID | PKFTs present | Easting | Northing | Koala evidence |
|---|---|---|---|---|
| NSI1 | | 539970 | 6934924 | × |
| NSI11 | | 543927 | 6955940 | × |
| NSI12 | | 546941 | 6955933 | × |
| NSI13 | | 543881 | 6257881 | × |
| NSI14 | | 546932 | 6957908 | × |
| NSI15 | | 543011 | 6959962 | × |
| NSI16 | | 543840 | 6961934 | × |
| NSI17 | | 546840 | 6963964 | × |

| | | | | |
|---|---|---|---|---|
| NSI18 | | 546928 | 6964940 | × |
| NSI19 | | 548946 | 6966848 | × |
| NSI2 | | 540884 | 6937946 | × |
| NSI20 | *E. tereticornis* | 543926 | 6968932 | ✓ |
| NSI3 | | 540977 | 6946973 | × |
| NSI4 | *E. tereticornis* | 541027 | 6948035 | ✓ |
| NSI6 | | 543867 | 6953911 | × |
| NSI7 | | 544859 | 6953982 | × |
| NSI8 | | 542928 | 6954940 | × |
| NSI9 | | 543926 | 6954941 | × |
| W NEW | *E. robusta* | 540866 | 6954015 | ✓ |
| W NEW 1 | | 547911 | 6954066 | × |
| W NEW 2 | | 545051 | 6965684 | × |
| W NEW 3 | *E. resinifera* | 544048 | 6965629 | ✓ |
| W NEW 4 | | 545814 | 6966005 | × |
| W NEW 5 | *E. robusta* | 545274 | 6967816 | ✓ |
| W NEW 6 | *E. robusta* | 548745 | 6965941 | ✓ |
| W11 | | 542878 | 6943021 | × |
| W15 | *E. robusta* | 540893 | 6952898 | ✓ |
| W16 | | 542000 | 6952989 | × |
| W18 | | 545958 | 6952890 | × |
| W19 | | 542914 | 6953980 | × |
| W26 | | 543017 | 6955903 | × |
| W28 | | 544928 | 6955940 | × |
| W30 | | 545927 | 6956939 | × |
| W34 | *E. robusta* | 542932 | 6958952 | ✓ |
| W35 | | 544975 | 6958858 | × |
| W39 | | 544977 | 6961863 | × |
| W40 | | 546852 | 6961899 | × |
| W41 | | 546927 | 6962940 | × |
| W6 | | 541860 | 6935995 | × |
| W8 | | 539936 | 6936937 | × |

# Appendix 2 – Tallest stratum species and mapped Regional Ecosystems

Tallest stratum species recorded at each field site and concordance with REDD and associated Technical descriptions. Site ID indicates the 'unique field site reference. RE = Regional Ecosystem; Field Survey Count Data (FSCD) is the number of individuals of each species recorded by the 8-point count undertaken at each site; Y = other tree species observed within 25 m radius but not represented in count; C = conformity score.

a. Mainland Redlands Coast

| Site_ID | RE | FSCD | | | | C |
|---|---|---|---|---|---|---|
| | | ≥ 3 | 2 | 1 | Y | |
| **Mainland Redlands Coast** | | | | | | |
| RCC_23r | | | Egra | Epro, Erob, Eter | | na |
| RCC_46 | | | Erac, silky oak | acacia | Ctra, Egra, white mahogany | na |
| RCC_65 | | Mqui | Lsua | Eter, Pine | Emic | na |
| RCC_84r | | Eter | | Ironbark, Mqui, Etes | | na |
| RCC_21 | 12.11.23/12.11.5j | Epla | Angophora, Epil | | Cint, Emic, Erac | 0.5 |
| RCC_07 | 12.11.23/12.11.5j/12.11.5h | Epil | Erac | Lcon | Eres | 1 |
| RCC_08 | | | Emic, Epil, Epla | Cint, Erac | | 1 |
| RCC_14 | | Epil | Erac | Cint, Ctra, Epla | | 1 |
| RCC_15 | | Emic | Epil | Angophora, Cint, White mahogany | Erac | 1 |
| RCC_10 | 12.11.5a | | Cgum, Emic | Angophora, Eres, Stringybark, White Mahogany, Lcon | Ironbark | 0.5 |
| RCC_11r | | | | Cint, Emic, Erac, Lcon, Mqui | Esee, Eres, Lsua | 0 |
| RCC_18 | | Ironbark | Angophora, White mahogany | Ctra | Emic, Epil, Esee, Stringybark | 0.5 |
| RCC_22 | | Eban | Ironbark | Angophora, Cint | Emic | 0.5 |
| RCC_26 | | | Efib, Epro, Lcon | Ccit, White mahogany | | 0.5 |
| RCC_27r | | Ccit | Epro | Lcon | Emic, Ironbark | 1 |
| RCC_33r | | Angophora | Emic, Epil, Epla | White mahogany, Lcon | Ccit, Epro, Ironbark, Mqui | 0 |
| RCC_48 | | | Epro, ironbark, Stingybark | Corymbia, White mahogany | Ccit, Emic | 1 |
| RCC_61r | | | Ccit, Ecre, Efib | Stringybark, White mahogany | Epro | 0.5 |
| RCC_37 | 12.11.5a/12.11.5k | Erac | Emic | Ctra, Ironbark | Cint, Esee, White mahagony | 0.5 |
| RCC_49 | 12.11.5a/12.11.5k/12.11.5a | White mahogany | Ccit, ironbark | Epro | Ctra | 1 |
| RCC_02 | 12.11.5h/12.11.5j/12.11.23 | Erac | | Ctra, Epla | Cint, Melaleuca | 1 |
| RCC_03 | | Erac | Lcon, Lsua | Cint | Ctra, Mqui, Acacia | 1 |
| RCC_01r | 12.11.5j | casuarina | Erac | | Ctra, Lsua | 1 |
| RCC_85 | | Epla, casuarina | | | Ctra, Erac | 0.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| RCC_86 | 12.11.5j/12.11.5h | casuarina | Epla | Erac | Cint | 0.5 |
| RCC_42r | 12.11.5k/12.11.5a | Ccit | | Angophora, Epro, Ironbark, Stringybark | | 1 |
| RCC_45 | | Angophora, Stringybark | | white mahogany | corymbia, ironbark | 1 |
| RCC_50r | | Strinybark | ironbark | Ccit, Etra, white mahogany | Ccit, Emic | 0.5 |
| RCC_56 | | Epro | | Cint, Stringybark, White mahogany, Lcon | Ccit, Ctra, Ecre, Efib, Emic | 0.5 |
| RCC_57 | | Lcon | | Ccit, Ctra, Epro | Emic, ironbark, white mahogany | 0.5 |
| RCC_06r | 12.3.11 | Mqui | Lsua | Lcon | Esee, Ironbark | 1 |
| RCC_19 | | Emol, Ironbark | | | | 0 |
| RCC_34 | | | | Ccit, Cint, Efib, Esid | Emic, Etin | 0.5 |
| RCC_36 | | casuarina | Ctra | Erac | Cint, white mahogany, Angophora, Lcon | 0 |
| RCC_52 | | Ecar | Lcon | Esee, Erac | Corymbia, Emc, Melaleuca | 0 |
| RCC_55 | 12.3.5/12.3.6 | Melaleuca | Eter | Lsua | | 1 |
| RCC_04r | 12.3.6 | Erac, Mqui | | Eter | Acacia | 0.5 |
| RCC_05 | | Melaleuca | | Cint, Epil, Acacia | Erac, Lsua | 0 |
| RCC_09 | | | Cint, white mahogany | Angophora, Emic, Epil, Eres | Esee, Ironbark | 0 |
| RCC_69 | | Melaleuca | Erac, Eter | Lsua | corymbia, ironbark | 0.5 |
| RCC_76r | | | Eter | Alei, Ctra, Esid | Cint, Ecre, Erac, Mqui | 0 |
| RCC_80 | | casuarina | Eter | ironbark, Lsua, rfsp | Mqui | 0.5 |
| RCC_82 | 12.5.2 | Eter | Pine | | Ironbark | 1 |
| RCC_54 | 12.5.2/12.3.11 | Eter | | Corymbia | | 1 |
| RCC_83r | 12.5.2/12.3.6/12.5.3 | casuarina | Egra, Eter | | Ccit, Emic | 0.5 |
| RCC_76 | 12.5.2/12.5.3 | Eter | Emic | Ironbark | Epro | 1 |
| RCC_75 | 12.5.3 | Erac | Ecre | | Ctra | 1 |
| RCC_63r | 12.5.3/12.9-10.4 | Erac | Emic | Ctra, white mahogany | Cgum, Cint, Erac | 1 |
| RCC_64 | 12.9-10.4 | Melaleuca | | Erac | Corymbia, Eter, Lsua | 1 |
| RCC_71 | | Erac | Emic | Alei | Cint, Ironbark | 1 |
| RCC_72 | | Erac | | Eres | | 1 |
| RCC_73 | | Ctra, Erac | | | | 1 |
| RCC_77 | | Erac | | Angophora, Cgum | | 1 |
| RCC_78 | | Cint | Eter | Erac | Cgum, Ctes, Ctra, Epat, Ironbark | 0.5 |
| RCC_79 | | Corymbia | | Emic | Esee, Erac, Stringybark, White mahogany | 0.5 |
| RCC_87 | | Emic, Erac | | Ctra, Esee | Cint, White mahogany | 0.5 |
| RCC_68 | 12.9-10.4/12.3.6 | Esee | Angophora, Emic | | Cint, Ctra, Melaleuca | 0.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **North Stradbroke Island** | | | | | | |
| NSI1 | 12.2.10 | Epla, Erac | Cgum | | | 1 |
| NSI6 | | Cgum, Erac | | | | 1 |
| NSI7 | | Cint, Epla | | | | 1 |
| W19 | | Epla | Cgum, Erac | | | 1 |
| NSI11 | | | | | | |
| NSI8 | | | | | | |
| W28 | | | | | | |
| NSI9 | | Epla | Cgum | | | 1 |
| W26 | | Epla | Cgum | | | 1 |
| W35 | | Epla, Pine/Cas | | | | 1 |
| NSI16 | | Epla | Cgum, Erac | | Pine/Cas | 1 |
| W30 | | Epla, Pine/Cas | | Cgum | | 1 |
| NSI18 | | Epla, Erac | | Cgum | | 1 |
| W40 | 12.2.10/12.2.13 | | | | | |
| W41 | | | | | | |
| NSI17 | | | | | | |
| W NEW 5 | 12.2.15 | Erob | Mqui | Cgum | | 0 |
| NSI12 | 12.2.15f | Cgum | | Alei, Epil, Erac, Lcon | | 0 |
| NSI4 | 12.2.6 | Lcon | Cint, Eter | Cgum | Alei | 0.5 |
| W16 | | Erac | | Cgum, Epil, Epla | | 1 |
| W18 | | Cint | Epil | Epla, Erac | | 1 |
| NSI13 | | Epil | Pine/Cas | Cgum | Epla, Erac | 1 |
| W NEW 3 | | Alei, Epil | | Eres | Erac | 0.5 |
| W NEW 2 | | Erac, Pine/Cas | | Cgum | | 1 |
| W39 | | | | | | |
| W NEW 4 | | Erac | Cgum | Epil, Epla | Pine/Cas | 1 |
| W34 | 12.2.7 | | Epat, Erob, Lsua | Alei, Cint | Epil, Eter | 0.5 |
| NSI20 | | Mqui | Cint, Pine/Cas | Eter | Erob, Lcon | 1 |
| W NEW 6 | | Cgum, Erob | | Alei | Erac | 0 |
| NSI19 | | Mqui, Pine/Cas | | | | 1 |
| W8 | 12.2.8 | Epil | | Lcon | | 1 |
| NSI3 | | Epil | | Cint, Lcon | | 1 |
| W15 | | Mqui | Epil, Eron | Alei | Corymbia | 0.5 |
| NSI14 | | Epil | Erac | Cint | Cgum | 1 |
| NSI15 | | Pine/Cas | | Cgum, Epil, Erac | Alei | 1 |
| NSI2 | 12.2.9/12.2.10 | Epla, Pine/Cas | | | | 1 |
| W6 | non-rem | Cgum | Epil | Erac | | na |
| W11 | | Erac | Cgum, Epil | | Alei, Epla | na |
| W NEW | | Epil, Erob | | | Alei | na |
| W NEW 1 | | Cint, Pine/Cas | | | Epil | na |

# Appendix 3 – Regional Ecosystems associated with each koala habitat type

| Koala habitat type | Regional Ecosystem(s) |
|---|---|
| **Mainland Redland Coast** | |
| Secondary_A | 12.1.1 |
| | 12.1.1/12.1.2 |
| | 12.1.1/12.1.3 |
| | 12.1.1/12.3.6 |
| | 12.1.1/12.5.2 |
| | 12.11.23/12.3.11 |
| | 12.11.23/12.3.11/12.11.5a/12.11.5k |
| | 12.11.23/12.3.5 |
| | 12.11.23/12.3.6 |
| | 12.11.23/12.3.6/12.11.5j |
| | 12.11.3/12.11.5a/12.3.11 |
| | 12.11.3/12.11.5e/12.3.11 |
| | 12.11.3/12.3.11 |
| | 12.11.3/12.3.11/12.11.5a |
| | 12.11.3/12.3.11/12.11.5a/12.3.6 |
| | 12.11.5a/12.11.5k/12.3.11 |
| | 12.11.5a/12.3.11 |
| | 12.11.5a/12.3.11/12.11.5k |
| | 12.11.5e/12.3.11 |
| | 12.11.5k/12.11.5a/12.3.11 |
| | 12.11.5k/12.3.11/12.11.5a |
| | 12.12.14/12.3.6 |
| | 12.3.11 |
| | 12.3.11/12.1.1 |
| | 12.3.11/12.1.3/12.1.2 |
| | 12.3.11/12.11.23 |
| | 12.3.11/12.11.3 |
| | 12.3.11/12.11.3a |
| | 12.3.11/12.11.5a/12.11.3 |
| | 12.3.11/12.11.5a/12.11.5k |
| | 12.3.11/12.11.5k |
| | 12.3.11/12.11.5k/12.11.5a |
| | 12.3.11/12.3.6 |
| | 12.3.11/12.3.6/12.3.5a |
| | 12.3.11/12.5.2 |
| | 12.3.11/12.9-10.4 |
| | 12.3.11/12.9-10.4/12.5.2 |
| | 12.3.11a |

| | |
|---|---|
| | 12.3.11a/12.11.5k/12.11.5a |
| | 12.3.11a/12.3.11/12.11.5k |
| | 12.3.5 |
| | 12.3.5/12.11.23 |
| | 12.3.5/12.3.11 |
| | 12.3.5/12.3.6 |
| | 12.3.5/12.3.6/12.11.5j |
| | 12.3.5/12.3.6/12.5.2 |
| | 12.3.5/12.5.2 |
| | 12.3.5a/12.3.11 |
| | 12.3.6 |
| | 12.3.6/12.1.1 |
| | 12.3.6/12.1.1/12.5.2 |
| | 12.3.6/12.1.2 |
| | 12.3.6/12.1.3 |
| | 12.3.6/12.11.23 |
| | 12.3.6/12.11.5j |
| | 12.3.6/12.11.5j/12.3.11 |
| | 12.3.6/12.12.14 |
| | 12.3.6/12.12.14/12.11.23 |
| | 12.3.6/12.12.14/12.9-10.4 |
| | 12.3.6/12.3.11 |
| | 12.3.6/12.3.11/12.3.5 |
| | 12.3.6/12.3.5 |
| | 12.3.6/12.3.6 |
| | 12.3.6/12.5.2 |
| | 12.3.6/12.5.2/12.1.1 |
| | 12.3.6/12.5.2/12.3.5 |
| | 12.3.6/12.5.3 |
| | 12.3.6/12.5.3/12.5.2 |
| | 12.3.6/12.9-10.4 |
| | 12.3.6/12.9-10.4/12.1.1 |
| | 12.3.6/12.9-10.4/12.3.5 |
| | 12.3.6/12.9-10.4/12.5.2 |
| | 12.5.2 |
| | 12.5.2/12.1.1 |
| | 12.5.2/12.1.2 |
| | 12.5.2/12.1.3 |
| | 12.5.2/12.3.11 |
| | 12.5.2/12.3.5/12.3.6 |
| | 12.5.2/12.3.6 |
| | 12.5.2/12.3.6/12.3.5 |

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| | 12.5.2/12.5.3 |
| | 12.5.2/12.5.3/12.1.1 |
| | 12.5.2/12.5.3/12.1.2 |
| | 12.5.2/12.5.3/12.3.6 |
| | 12.5.2/12.5.3/12.9-10.4 |
| | 12.5.2/12.9-10.4 |
| | 12.9-10.4/12.11.23/12.3.11 |
| | 12.9-10.4/12.12.14/12.3.11 |
| | 12.9-10.4/12.12.14/12.3.6 |
| | 12.9-10.4/12.3.11 |
| | 12.9-10.4/12.3.6 |
| | 12.9-10.4/12.3.6/12.12.14 |
| | 12.9-10.4/12.5.2 |
| | 12.9-10.4/12.5.2/12.3.6 |
| Secondary_A / Secondary_B | 12.11.23/12.11.3a/12.11.5a/12.11.5k |
| Secondary_A / Secondary_C | 12.1.1/12.5.2/12.5.3 |
| | 12.3.11/12.3.6/12.5.3/12.5.2 |
| | 12.3.6/12.1.2/12.1.1 |
| | 12.3.6/12.1.3 |
| | 12.3.6/12.5.2/12.1.1/12.5.3 |
| | 12.3.6/12.5.2/12.5.3 |
| | 12.3.6/12.5.3 |
| | 12.3.6/12.5.3/12.5.2 |
| | 12.3.6/12.9-10.4/12.5.3 |
| | 12.3.6/12.9-10.4/12.5.3/12.5.2 |
| | 12.5.2/12.1.1/12.5.3 |
| | 12.5.2/12.3.11/12.3.6/12.5.3 |
| | 12.5.2/12.3.6/12.5.3 |
| | 12.5.2/12.3.6/12.5.3/12.3.11 |
| | 12.5.2/12.5.3 |
| | 12.5.2/12.5.3/12.1.1 |
| | 12.5.2/12.5.3/12.3.6 |
| | 12.5.2/12.9-10.4/12.5.3 |
| | 12.9-10.4/12.3.6/12.5.3 |
| | 12.9-10.4/12.5.2/12.5.3 |
| Secondary_A / Secondary_C / Other | 12.5.2/12.5.3/12.3.6/12.1.2 |
| Secondary_A / Other / Secondary_C | 12.5.2/12.1.2/12.5.3/12.3.6 |
| | 12.5.2/12.1.3/12.1.2/12.5.3 |
| | 12.5.2/12.1.3/12.5.3 |
| Secondary_A / Other | 12.1.1/12.1.2 |
| | 12.1.1/12.1.3 |
| | 12.1.1/12.1.3/12.3.6 |

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| | 12.1.1/12.3.11/12.1.2/12.1.3 |
| | 12.1.1/12.3.6/12.1.3 |
| | 12.11.23/12.3.11/12.11.5j |
| | 12.11.23/12.3.6/12.11.5j |
| | 12.11.23/12.9-10.4/12.3.11/12.11.5j |
| | 12.11.5a/12.11.5k/12.3.6/12.3.1 |
| | 12.3.11/12.1.3/12.1.2 |
| | 12.3.11/12.11.23/12.11.5j |
| | 12.3.11/12.11.5j/12.11.5k |
| | 12.3.5/12.11.5j/12.11.23/12.3.6/12.11.5h |
| | 12.3.5/12.3.6/12.11.5j/12.11.23 |
| | 12.3.6/12.1.1/12.1.3 |
| | 12.3.6/12.11.23/12.11.5j |
| | 12.3.6/12.11.5j |
| | 12.3.6/12.11.5j/12.11.23 |
| | 12.3.6/12.11.5j/12.11.23/12.11.5h |
| | 12.3.6/12.11.5j/12.11.23/12.3.11 |
| | 12.3.6/12.11.5j/12.11.23/12.3.5 |
| | 12.3.6/12.11.5j/12.3.11/12.11.23 |
| | 12.3.6/12.11.5j/12.3.5/12.11.23 |
| | 12.3.6/12.3.1 |
| | 12.3.6/12.3.1/12.11.3/12.11.5a |
| | 12.3.6/12.3.1/12.11.5a |
| | 12.3.6/12.3.5/12.11.5j/12.11.23 |
| | 12.5.2/12.1.2 |
| Secondary_B | 12.11.3 |
| | 12.11.3/12.11.5a |
| | 12.11.3/12.11.5k/12.11.5a |
| | 12.11.3a/12.11.10 |
| | 12.11.3a/12.11.10/12.11.5a |
| | 12.11.3a/12.11.5a/12.11.10 |
| | 12.11.5e |
| | 12.11.5e/12.11.3 |
| | 12.11.5e/12.11.5a |
| Secondary_B / Secondary_A | 12.3.3d |
| Secondary_B / Secondary_C | 12.11.3/12.11.5a |
| | 12.11.3/12.11.5a/12.11.5k |
| | 12.11.3/12.11.5k/12.11.5a |
| Secondary_B / Secondary_C / Other | 12.11.3/12.11.5k/12.3.1/12.11.5a |
| Secondary_B / Other / Secondary_C | 12.11.3/12.11.10/12.11.5k/12.11.5a |
| Secondary_C | 12.11.23 |
| | 12.11.23/12.11.5a/12.11.5k |

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| | 12.11.23/12.11.5a/12.11.5k/12.11.3a |
| | 12.11.23/12.11.5j |
| | 12.11.23/12.11.5j/12.12.14 |
| | 12.11.23/12.9-10.4/12.11.5j |
| | 12.11.5a |
| | 12.11.5a/12.11.10 |
| | 12.11.5a/12.11.23/12.11.5k |
| | 12.11.5a/12.11.3 |
| | 12.11.5a/12.11.5e |
| | 12.11.5a/12.11.5j |
| | 12.11.5a/12.11.5k |
| | 12.11.5a/12.11.5k/12.11.5a |
| | 12.11.5a/12.11.5k/12.9-10.4 |
| | 12.11.5k |
| | 12.11.5k/12.11.5a |
| | 12.11.5k/12.11.5a/12.11.23 |
| | 12.11.5k/12.12.14/12.11.5a |
| | 12.12.14 |
| | 12.12.14/12.11.5j |
| | 12.12.14/12.11.5k |
| | 12.12.14/12.9-10.4 |
| | 12.12.14/12.9-10.4/12.11.5k |
| | 12.5.3 |
| | 12.5.3/12.3.6 |
| | 12.5.3/12.5.2 |
| | 12.5.3/12.9-10.4 |
| | 12.9-10.17d |
| | 12.9-10.17d/12.9-10.17c |
| | 12.9-10.19a |
| | 12.9-10.4 |
| | 12.9-10.4/12.11.23 |
| | 12.9-10.4/12.11.5a/12.11.5k |
| | 12.9-10.4/12.11.5j |
| | 12.9-10.4/12.12.14 |
| | 12.9-10.4/12.5.3 |
| Secondary_C / Secondary_A | 12.5.3/12.3.6 |
| | 12.5.3/12.3.6/12.5.2/12.9-10.4 |
| | 12.5.3/12.5.2 |
| | 12.5.3/12.5.2/12.3.6 |
| | 12.9-10.4/12.5.3/12.5.2 |
| Secondary_C / Secondary_B | 12.11.5a/12.11.3 |
| | 12.11.5a/12.11.3/12.11.5k |

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|---|---|
| | 12.11.5k/12.11.3/12.11.5a |
| | 12.11.5k/12.11.5a/12.11.3 |
| Secondary_C / Other | 12.11.23/12.11.5h |
| | 12.11.23/12.11.5j |
| | 12.11.23/12.11.5j/12.11.5h |
| | 12.11.23/12.9-10.4/12.11.5j |
| | 12.11.5a/12.11.5h |
| | 12.11.5a/12.11.5j |
| | 12.11.5k/12.11.5h/12.11.5a |
| | 12.11.5k/12.11.5j/12.11.5a |
| | 12.9-10.4/12.11.5j |
| Secondary_C / Unknown | 12.11.5a/12.11.23a/12.11.5k |
| Other | 12.1.2 |
| | 12.1.2/12.1.1 |
| | 12.1.2/12.1.3 |
| | 12.1.2/12.3.6 |
| | 12.1.3 |
| | 12.1.3/12.1.2 |
| | 12.1.3/12.1.2/12.11.5j |
| | 12.11.10 |
| | 12.11.10/12.11.5a |
| | 12.11.10/12.11.5k |
| | 12.11.10/12.11.5k/12.11.5a |
| | 12.11.10/12.3.1/12.11.3 |
| | 12.11.23/12.11.5j/12.3.6 |
| | 12.11.5h |
| | 12.11.5h/12.11.5j |
| | 12.11.5j |
| | 12.11.5j/12.11.5a/12.11.5h |
| | 12.11.5j/12.11.5h |
| | 12.11.5j/12.11.5k |
| | 12.11.5j/12.11.5k/12.12.14 |
| | 12.11.5j/12.3.11 |
| | 12.11.5j/12.3.6 |
| | 12.3.1 |
| | 12.3.1/12.11.3 |
| | 12.3.8 |
| Other / Secondary_A | 12.1.2/12.1.1 |
| | 12.1.3/12.1.1 |
| | 12.1.3/12.1.2/12.3.11 |
| | 12.1.3/12.1.2/12.5.2 |
| | 12.1.3/12.3.5/12.1.2/12.3.6 |

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| | 12.1.3/12.5.2/12.1.2 |
| | 12.11.23/12.11.5j/12.3.6 |
| | 12.11.5j/12.11.23/12.11.5h/12.3.5 |
| | 12.11.5j/12.11.23/12.3.5/12.11.5h |
| | 12.11.5j/12.11.23/12.3.6 |
| | 12.11.5j/12.11.23/12.3.6/12.11.5h |
| | 12.11.5j/12.11.5a/12.3.6 |
| | 12.11.5j/12.3.11 |
| | 12.11.5j/12.3.6 |
| | 12.11.5j/12.3.6/12.11.23/12.11.5h |
| | 12.11.5j/12.3.6/12.11.23/12.11.5h/12.3.5 |
| | 12.11.5j/12.3.6/12.11.23/12.3.5 |
| | 12.11.5j/12.5.2/12.3.6/12.11.23 |
| | 12.12.14/12.11.5j/12.3.6 |
| Other / Secondary_A / Secondary_C | 12.1.2/12.5.2/12.5.3 |
| | 12.1.2/12.5.2/12.5.3/12.3.6 |
| | 12.1.3/12.5.2/12.5.3/12.3.6 |
| Other / Secondary_B | 12.11.10/12.11.3 |
| Other / Secondary_C | 12.1.3/12.1.2/12.9-10.4 |
| | 12.1.3/12.11.5j/12.1.2/12.11.23 |
| | 12.1.3/12.9-10.4/12.1.2 |
| | 12.11.5h/12.11.5j/12.11.23 |
| | 12.11.5h/12.11.5k |
| | 12.11.5j/12.1.3/12.11.23/12.11.5h/12.1.2 |
| | 12.11.5j/12.11.23 |
| | 12.11.5j/12.11.23/12.1.3/12.11.5h/12.1.2 |
| | 12.11.5j/12.11.23/12.11.5h |
| | 12.11.5j/12.11.5a |
| | 12.11.5j/12.12.14 |
| | 12.11.5j/12.9-10.4 |
| Other / Unknown | 12.11.5j/12.115h |
| **North Stradbroke Island** | |
| Secondary_A | 12.2.7 |
| | 12.2.7a |
| | 12.2.8 |
| | 12.3.20 |
| Other/Secondary_A | 12.2.14/12.2.7 |
| Other | 12.1.2 |
| | 12.1.3 |
| | 12.12.19 |
| | 12.2.1 |
| | 12.2.10 |

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|---|---|
| | 12.2.10/12.2.13 |
| | 12.2.12 |
| | 12.2.13 |
| | 12.2.13/12.2.10 |
| | 12.2.14 |
| | 12.2.15 |
| | 12.2.15a |
| | 12.2.15f |
| | 12.2.16 |
| | 12.2.2 |
| | 12.2.5 |
| | 12.2.6 |
| | 12.2.9 |
| | 12.2.9/12.2.10 |
| | 12.2.9/12.2.13 |