Koala Habitat & Population Assessment

Lismore Local Government Area (part)

Final Report to Lismore City Council

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Executive Summary

Effective long-term monitoring of koala populations is fundamental to understanding changes in distribution and abundance. Under the auspices of Council's Biodiversity Management Strategy and pursuant to recommendations associated with the approved Lismore Comprehensive Koala Plan of Management (CKPoM), this project analysed koala records for 2011 - 2016 while additionally interrogating Council's vegetation mapping & associated koala habitat categorisations by sampling areas identified as *Preferred Koala Habitat* (PKH). Direct-count survey techniques were also utilised so that a koala population estimate for the CKPoM planning area could be derived.

Testing the PKH mapping and estimating the numbers of koalas were addressed by way of sampling across and beyond the approximately 20,870 ha area covered by the CKPoM using a 350 m point-based grid to identify potential sampling points where they occurred within areas mapped as PKH. Details of vegetation composition that included determining the presence/absence of preferred koala food trees and the presence / absence of evidence of use by koalas in the form of diagnostic koala faecal pellets were collected at each field site. Counts of koalas at each sampling point were also undertaken using 25 m fixed-radius and large-area (~1 ha) transect searches.

Examination of 674 Wildlife Atlas records for the most recent koala generation (*i.e.* 2011 – 16) confirmed that koalas remain widely distributed across the Lismore Local Government Area (LGA), their estimated *Extent of Occurrence* (EoO) of 128,660 ha falling within the range of variation informing that of the two preceding koala generations. Across the LGA, the *Area of Occupancy* (AoO) estimate for the 2011-16 koala generation was calculated to be ~ 31% of available habitat, a value that did not differ significantly from that of the immediately preceding three koala generations. Within the CKPoM planning area, occupancy for the 2011 – 16 koala generation was estimated at ~ 50% of available habitat. Areas of Generational Persistence / *Core Koala Habitat* for the three koala generations leading up to this assessment were widespread but concentrated in two main areas of the LGA, the first around Dorroughby – Dunoon – Rosebank, the second within the CKPoM planning area wherein the extent of *Core Koala Habitat* comprised approximately 70 % of currently available areas of PKH.

Information from the Friends of the Koala (FoK) records database for 2011 – 16 revealed that disease, vehicle-strike and domestic dog attack remain the primary contributors to koala mortality across the LGA. Collectively, vehicle-strike and domestic dog attack accounted for 25% of all known koala mortalities, while deaths from disease accounted for a further 50% of known mortalities. Detailed analysis of vehicle-strike data identified a number of black spots for koalas inside and

outside of the CKPoM planning area, particularly along the Bruxner Highway and Wyrallah Road. The incidence of domestic dog attack, occurring at highest density within the most urbanised parts of the LGA, remains an issue for ongoing community engagement.

Within the CKPoM planning area, 70 of the 136 sites initially identified for sampling were surveyed following approval from the landowners to access sites on private property. Twenty-six of the sampled sites did not contain *Preferred Koala Food Trees* (PKFTs), this result implying that approximately 37% of the corresponding habitat underpinning the survey design was thus unlikely to be PKH. Evidence of habitat use by koalas was recorded at 34 of the remaining 44 sites at which PKFTs were present, this result implying that approximately 77% of the habitat otherwise available to koalas was being utilised by koalas at the time of the survey, a value approximating that predicted by the earlier GPA/*Core Koala Habitat* estimate. Five koalas were recorded within the 13.7 ha sampled by 25 m fixed-radius searches, while 19 koalas were recorded within the 61.6 ha sampled by transect searches; these data translate to density estimates across the CKPoM planning area of 0.31 - 0.36 koalas ha^{-1} respectively. These two estimates did not differ statistically and data was consequently pooled to give a final density estimate of 0.34 koalas ha^{-1}. When extrapolated across the 5,273 ha of PKH currently mapped within the CKPoM planning area, a koala population size estimate of ~ 1,800 koalas results.

Forty-one koalas (12M, 15F, 14 sex unknown) were observed during the survey. Koala joeys were observed on three of the 13 adult females that were observed, an outcome that should not be interpreted as an indication of the total numbers of breeding females because the presence of small(er) pouch young remained unknown. Approximately half of these observations occurred in a localised area of approximately 1,600 ha between the localities of Tregeagle, Wyrallah and Monaltrie, thus alluding to the presence of a local source population or hub in this area. To the extent where it was readily apparent upon field observations, clinical signs of Chlamydiosis in the form of conjunctivitis and/or wet-bottom/dirty-tail were observed in 10 of the 41 koalas, three of which were sufficiently advanced to warrant notification to FoK.

Results from the survey create a koala conservation and management conundrum given that the Lismore area has one of, if not the highest disease-mediated koala mortality rates being reported from eastern Australia, yet the habitat utilisation/occupancy rate in the order of 50 - 70% of the available habitat and a population estimate of approximately 1,800 animals occupying arguably less than 3,500 ha of PKH implies the presence of a demographically robust population. The reasons for such a circumstance are unclear, but are speculated to be associated with a high carrying capacity habitat on high-nutrient soils and a lack of fire across the CKPoM planning area landscape. The often sparsely distributed nature of the preferred food tree resource across a largely rural landscape predicates against creation of a formal linkage network, instead suggesting that a program of ongoing and widespread plantings across the planning area as a means of increasing the extent of cover would be a more effective strategy.

There is increasing evidence to support further speculation that the high disease-mediated mortality rate of koalas within the LGA may be associated with a history of inbreeding that has resulted in the loss of genetic information which may otherwise assist the immunological response. The progressive introduction of new genetic material associated with koala populations occupying habitat in north-eastern parts of the LGA is expected to improve the genetic fitness of the CKPoM planning area population such that disease rates may reduce in future generations. Regardless, anthropogenic mortality drivers, including domestic dog attack and vehicle-strike, both individually and collectively still have the potential to initiate and drive population decline across the study area.

Baseline data collected by this study provides a background against which a longer-term koala population monitoring program can be implemented. In addition to modifying the current array of field sites to remove those that do not contain PKFTs, other recommendations arising from the study include the need for an ecological history of the planning area to be documented, ongoing community education regarding the management of domestic dogs in urban areas, weed control in bushland remnants and pursuing funding for measures to reduce vehicle-strike potential at identified black spots. An intra-generational monitoring program based on the ongoing and ideally random sampling every two years from the pool of sites established for this study, supported by a review of historical records every third monitoring event will also assist longer-term population monitoring by informing on changes in distribution and population wellbeing, as well as any changes to the disease-mediated mortality rate and the efficacy of programs intended to reduce domestic dog attack and vehicle-strike. To this end, ongoing recruitment of additional field sites from amongst those initially identified for sampling by this study will be required.

…………………………………………

Introduction

Long-term monitoring of koala populations is necessary to inform on any ongoing changes in koala distribution and abundance. At the landscape scale, such changes are arguably best measured over generational time frames. In 2011, the distribution and abundance of koalas within the Lismore LGA was assessed for the first time by way of an analysis of 3,619 historical records covering the time 1949 to 2010 (Biolink 2011). This study reported a widespread distribution of koalas across the Lismore LGA, including a trend of range expansion of approximately 24% in the key range parameter *Extent of Occurrence* (EoO) over the three preceding koala generations leading up to the assessment. There was also evidence of long-term koala generational persistence in several areas (Biolink 2011). However, while the Biolink (2011) study assisted development of a Comprehensive Koala Plan of Management (CKPoM) (Lismore City Council 2013), no field surveys were undertaken. Hence a knowledge gap existed in terms of information regarding such things as the efficacy of Council's koala habitat mapping, as well as koala population size.

Lismore City Council (LCC) recently adopted a Biodiversity Management Strategy (BMS) for the Lismore Local Government Area (Lismore City Council 2015). The BMS guides biodiversity management across the LGA and reflects the aims of various regional biodiversity plans. In this context LCC has an approved CKPoM which applies to an area of approximately 21,000 ha located in the south-east of the LGA. The BMS continues to implement management actions outlined in the CKPoM which was adopted and approved in 2013 in accord with *State Environment Planning Policy* (SEPP) *No. 44 Koala Habitat Protection*. Action 29 of the CKPoM refers to the need for a study of the density and population of koalas in the area to which the CKPoM applies.

The aim of this project was to collect additional data on distribution, population size and habitat utilisation/occupancy rates of koala populations across and within parts of the Lismore LGA area and to use more recent koala records from community and government sources to inform Council about trends associated with the most recent koala generation (2011-2016). In no particular priority, this was achieved by:

1. Examining the current distribution of koalas across the Lismore LGA,

2. Determining the habitat utilisation /occupancy rate by koalas of available habitat across that area covered by the approved Lismore CKPoM,

3. Estimating koala density and population size,

4. Examining landscape connectivity issues, and

5. Identifying the most common causes of mortality across the LGA and advise on mortality reduction programs.

Methods

Study Area

Unless otherwise specified, the study area referred to herein is congruous with that encapsulated by the planning boundary of Council's adopted CKPoM. The CKPoM planning boundary encompasses an area of 20,870 ha bounded by Wilsons River in the north and west and the administrative boundary with Ballina shire in the east. In the south, the boundary follows several minor roads before connecting with the drainage canal south of Tuckean Island Road and thereafter across the southern boundary of Tuckean Nature Reserve. For survey and assessment purposes however and concordant with our 2011 study, we extended this boundary south to the Richmond River to better reflect natural barriers to koala dispersal and recruitment and so enable the sampling of outlying koala populations and associated habitat areas.

Records Analysis

Current Distribution

a) Extent of Occurrence(EoO)

Koala records for the Lismore LGA for the most recent koala generation (2011 – 2016 incl.) were downloaded from the NSW Wildlife Atlas website. Using the outermost records only, a Minimum Convex Polygon indicating the known EoO of koalas for this period was constructed for comparison to estimates for the immediately preceding two koala generations 1999-2004 and 2005-10 as estimated by Biolink (2011).

*b) Area of Occupancy (AoO)_*

AoO estimates were also calculated for the 2011–16 koala generation both across the LGA and additionally within the CKPoM planning boundary; this was done using the same 2.5 km grid cells developed for purposes of the Biolink (2011) report. Where appropriate, AoO output was compared to that of the immediately preceding generations.

c) Generational Persistence

Grid cells determined to contain koala records for each of the three koala generations 1999-2004, 2005-10, and 2011-16 were deemed to be areas of generational persistence that were sustaining resident koala populations, the habitat contained therein thus warranting recognition as *Core Koala Habitat*.

Mortality trends

Friends of the Koala (FoK) supplied details of koala call-outs for the Lismore LGA for the period 2011-16. These records were examined in terms of mortality trends in disease, vehicle-strike and domestic dog attack.

Vehicle-strike records were the subject of particular attention, our intent to develop an objective procedure for more widespread application that:

a) Facilitated the identification of the most important vehicle-strike areas by initially calculating the average Euclidian distance between each koala vehicle-strike and the five closest vehicle-strikes. Central tendency measures were determined for the these data and the resulting 95% confidence interval 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 subsequently excluded from more detailed analysis given that they represented geographically isolated events.
b) Corrected for the under-reporting of koala vehicle-strike on 'rural' roads (< 50% tend to be reported - Phillips *et al.*, 2015). This was done by doubling the period over which vehicle-strike records on rural roads were considered such that data from two, rather than one, koala generation (*i.e.* both 2005-2010 and 2011-2016) was utilised. To qualify as a black-spot in rural areas, records were also required to span both generations. Urban roads were defined as those traversing areas where adjacent property lots were typically small (i.e. < 600 m^2) in area.
c) Enabled objective partitioning of urban and rural road vehicle-strike clusters whereby sections contributing disproportionately greater numbers of vehicle-strikes within identified clusters could then be isolated by partitioning each km in terms numbers of road strikes km^{-1} $generation^{-1}$.

For the purposes of black spot identification, vehicle-strike data included all koalas reported to FoK because of a vehicle collision, whether this was fatal or not. In instances where rural vehicle-strike data was only present in only the most recent generation, any indicative black-spots were omitted because they did not show persistence over time and may therefore be due to more transient and/or localised events. Future monitoring events will reveal whether vehicle-strike in these areas is ongoing, which may see them designated as black-spots at subsequent monitoring events.

Field Survey

Vegetation mapping of the study area was overlain with a 350 m x 350 m point-based grid, each point becoming a potential sampling site where it occurred within a polygon categorised as *Preferred Koala Habitat* (PKH) (*i.e.* Primary, Secondary A and/or B koala habitat). Landholders on whose property potential sampling points occurred were consequently contacted by Council. Subject to landholder permission, at each sampling point a quantitative vegetation assessment of the tallest and mid-strata was undertaken. This involved recording growth form, height and species for the tallest and mid-strata within a 25 m radius of the sampling point, with abundance data gathered by way of identifying the closest standing live stem intersected by sighting over a maximum distance of ~15 m – 20 m along cardinal and intermediate compass points from the central sampling point. For the vegetation at the sampling point and associated polygon to be validated as PKH, preferred koala food trees (PKFTs) had to be present either within the general area of the site and/or encountered along subsequent transect searches.

Koala occurrence at each site was determined based on the presence/absence of koala faecal pellets within 1 m from the bases of PKFTs Swamp Mahogany, Tallowwood, Grey Gum and/or Forest Red Gum [*sensu lato* Phillips and Callaghan (2011)], or otherwise on the basis of a 10-person minute visual inspection in the event that PKFTs were not present within 50 m of the site coordinates.

A 25 m fixed radius (0.196 ha) search for koalas was also undertaken at each site regardless of whether koala faecal pellets were present, as was a 250 m x 40 m (or approximation thereof) transect [*sensu lato* Dique *et al*. (2003)], aligned along contours or otherwise standardized to optimize the area of habitat to be searched. Transect alignment was established prior to the commencement of survey work to minimise any potential for bias if a koala was sighted in the immediate vicinity during the preliminary assessment. To test for significant differences between results obtained by the two direct count methods, results for each site were standardized to the number of koalas ha^{-1} and then 'normalised' (by addition of 0.5 to all data to eliminate zeros prior to a $\log_{10}$ transformation). We then tested variances for each method for homogeneity prior to using a *t*-test to compare the means.

Opportunistic sightings of koalas were also recorded on a one-off basis throughout the survey period. This means that any koala sightings along subsequent traverses of the same area/road during the survey period were disregarded. Where possible these observations included details of the koala's sex, health and the presence of pouch and/or back young.

Results

Records Analysis

Koala Distribution

a) Extent of Occurrence

Six hundred and seventy-four records of koalas for the Lismore LGA and covering the period 2011–2016 were obtained from the NSW Wildlife Atlas database. The distribution of these records (Figure 1) confirmed that koala distribution remains widespread across an area of approximately 128,660 ha, a value that falls within the range of EoO estimates for the two preceding koala generations 1999–2004 (108,350 ha) and 2005–2010 (146,554 ha) reported by Biolink (2011).

b) Area of Occupancy

Across the LGA, the AoO estimate for the 2011-16 koala generation was calculated to be 31.14 ± 0.94% (SE) of available habitat. This estimate was not significantly different from that of the 29.77% ± 0.73% (SE) estimated by Biolink (2011) for the immediately preceding three koala generations (Levene's Test: F = 0.6047, 9_{df}, P = 0.233; t = -1.1540, 18_{df}, P = 0.2636). The *AoO* within the CKPoM planning area boundary for the 2011–16 koala generation was estimated to be 49.16% ± 0.02% (SE) of available habitat.

c) Generational Persistence

Forty-six of the 262 2.5 km x 2.5 km grid cells located within the historical EoO of koalas across the LGA returned evidence of generational persistence. Cells evidencing generational persistence were primarily clustered in the north and south of the LGA, the first around Dorroughby – Dunoon – Rosebank, the second within the CKPoM planning area wherein 25 of 36 (~ 70%) of the associated 2.5 km x 2.5 km grid cells contained evidence of generational persistence. Figure 2 illustrates areas of generational persistence that can currently be identified on the basis of known records.

Lismore Koala Population Assessment 2017

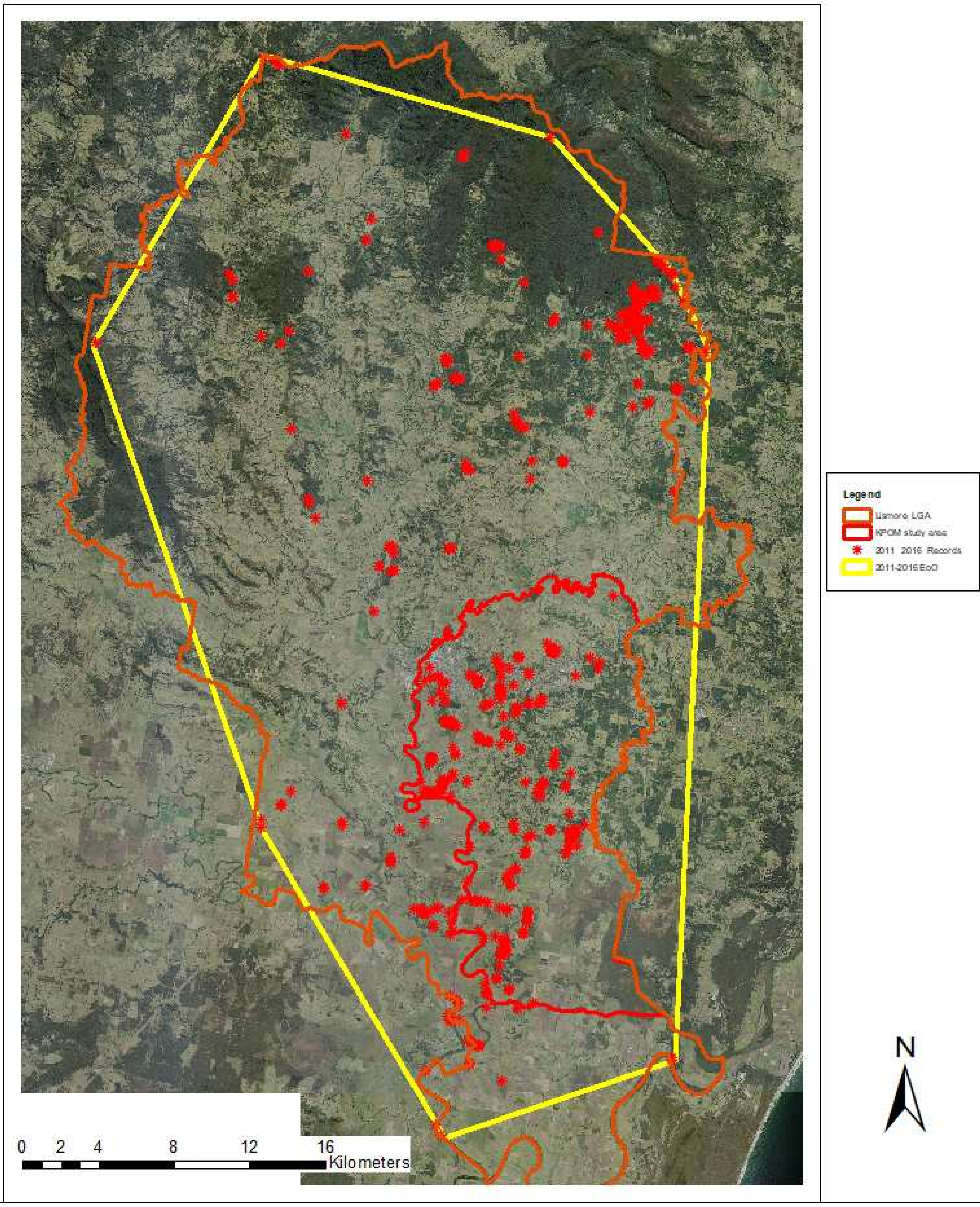

Figure 1. Koala Extent of Occurrence 2011 - 2016.

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Date of Map: September, 2017

Lismore Koala Population Assessment 2017

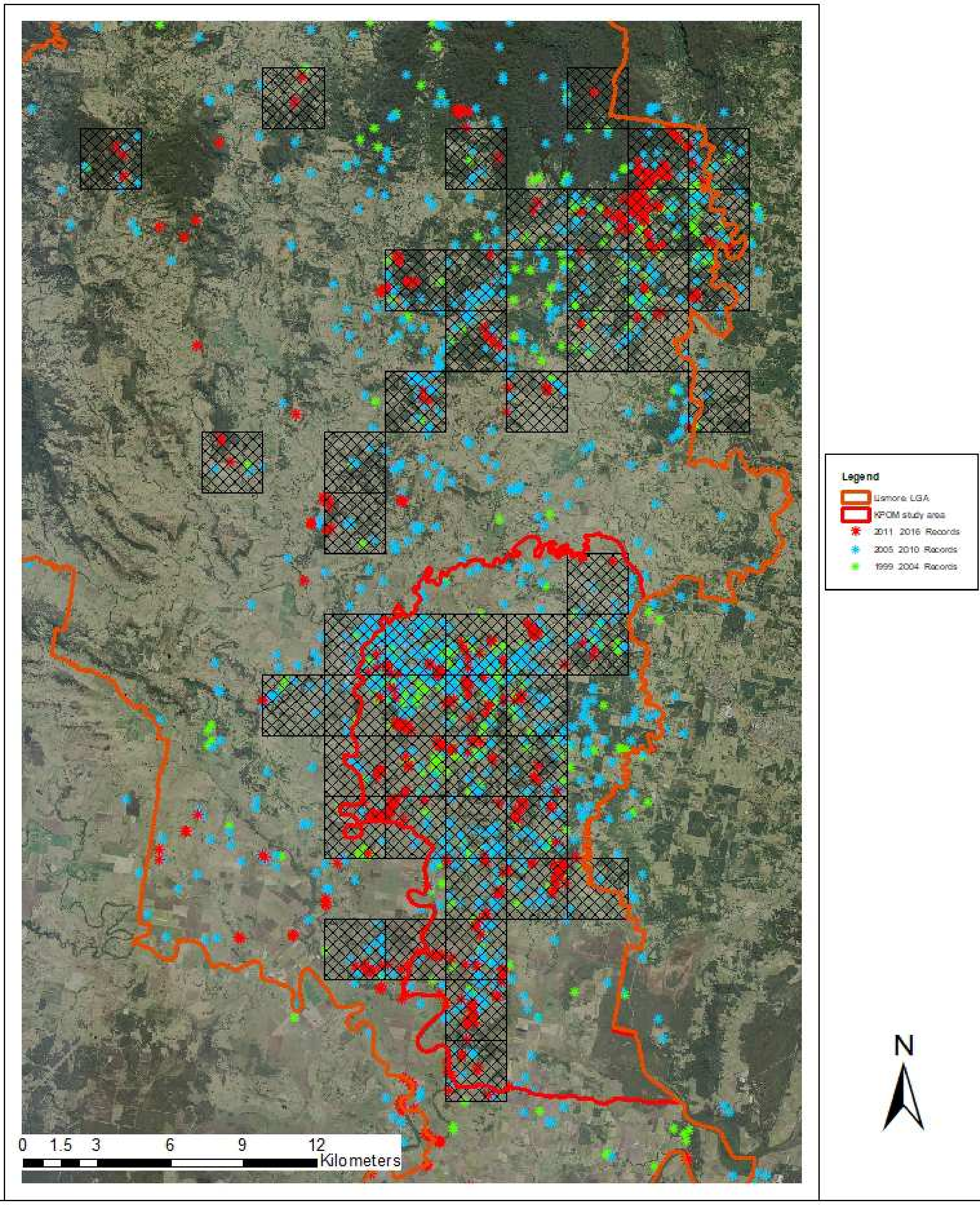

Figure 2. Known areas of Generational Persistence / Core Koala Habitat

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Koala Mortality

The FoK database contained information associated with 2,221 'koala-calls' for the period 2011-16, 842 of which related to a koala mortality. The predominant factors contributing to known koala mortalities across the LGA were disease (420/842 = 50%), vehicle-strike (147/842 = 17.5%) and dog attack (66/842 = 8%). A further 8.5% of mortalities were due to a disparate range of factors including advanced age, injuries resulting from indeterminate causes or becoming orphaned, while causes behind the remaining 16% of mortalities were unknown. The three primary contributing factors associated with known mortalities are discussed in more detail in the following sections.

a) Disease

Seven hundred and twenty-one of the calls made to FoK during the period 2011-2016 pertained to diseased koalas, Chlamydiosis being the most commonly attributed disease. A disproportionally greater number of these animals were females (1.49 females: 1 male). Partitioning the data according to years and despite an apparent increase in the 2016 reporting period (Figure 3), disease rates (as measured by confirmed mortalities) did not fluctuate significantly (Grubbs' Test: $Z = 1.88$, $P > 0.05$).

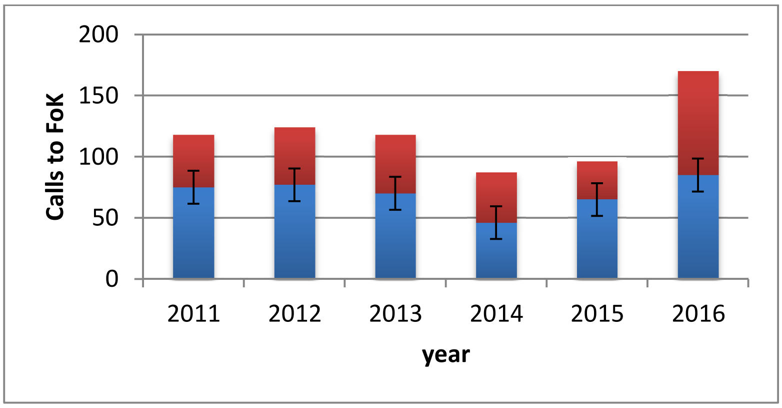

Figure 3: Trends in both the numbers of diseased koalas reported to the Friends of the Koala (FoK) and associated mortalities over the period 2011 - 2016. Blue sections of columns show the number of calls to FoK that related to a koala mortality event, the red section of the column shows calls that did not relate to a koala death. Error bars display the standard deviation in mortality rates.

Vehicle-strike

During the period 2011-2016 there were 200 koala vehicle-strikes reported to FoK, ~74% ($n = 147$) of which resulted in the death of the koala. For the purposes of correcting the under-reporting in rural areas to assist black spot analysis, a further 42 vehicle strikes from rural roads over the period 2005–2010 were also included. Collectively, these data indicate that a significantly greater proportion of vehicle-strikes on rural roads result in a confirmed koala fatality, compared to those on urban roads (83% *vs* 53%; X^2=39.43, 1_{df}, P< 0.001). Cases in which vehicle-strike did not result in the death of a koala had one of several outcomes, including being taken into care and later released, disappearance before rescue, or the incident was recorded as 'advice only'. Male koalas were over-represented in vehicle-strikes (1.64 males: 1 female). Most vehicle-strike occurred on roads with high traffic loads, particularly in areas where patches of native vegetation occurred in close proximity.

High rates of koala vehicle-strike occurred in several locations along Wyrallah Road – collectively accounting for 25% of all known vehicle related mortalities within the LGA. In the context of the two previous koala generations, the number of koala fatalities occurring along Wyrallah Road is progressively increasing (Figure 4). The Bruxner Highway/Ballina Road similarly accounted for a further 23% of all known motor vehicle related mortalities.

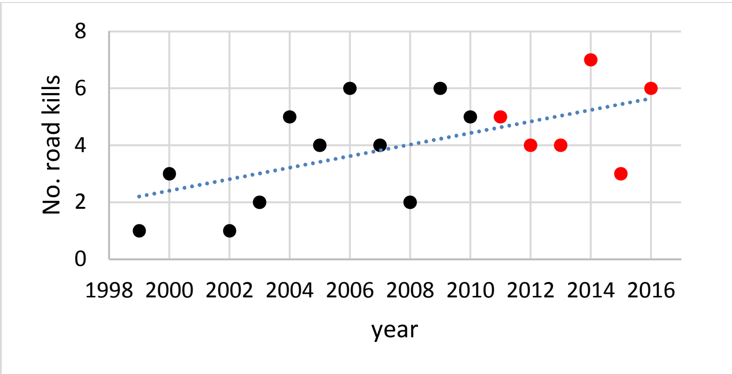

Figure 4: Changes in the rates of koala vehicle-strike along Wyrallah Road in the Lismore LGA, with data for the most recent koala generation (2011-2016) in red, that in black being data from the two immediately preceding koala generations (*i.e.* 1999 – 2004 & 2005 – 10) as reported by Biolink (2011).

Application of the clustering and generational parameters resulted in the capture of 189 vehicle-strike records and the identification of five black spots for koala vehicle-strike within the Lismore LGA (Figure 5). Table 1 provides a summary of the vehicle-strike data in terms of road length and the numbers of koalas being struck by vehicles at each of these black spots, both as a total figure and as km^{-1} $generation^{-1}$.

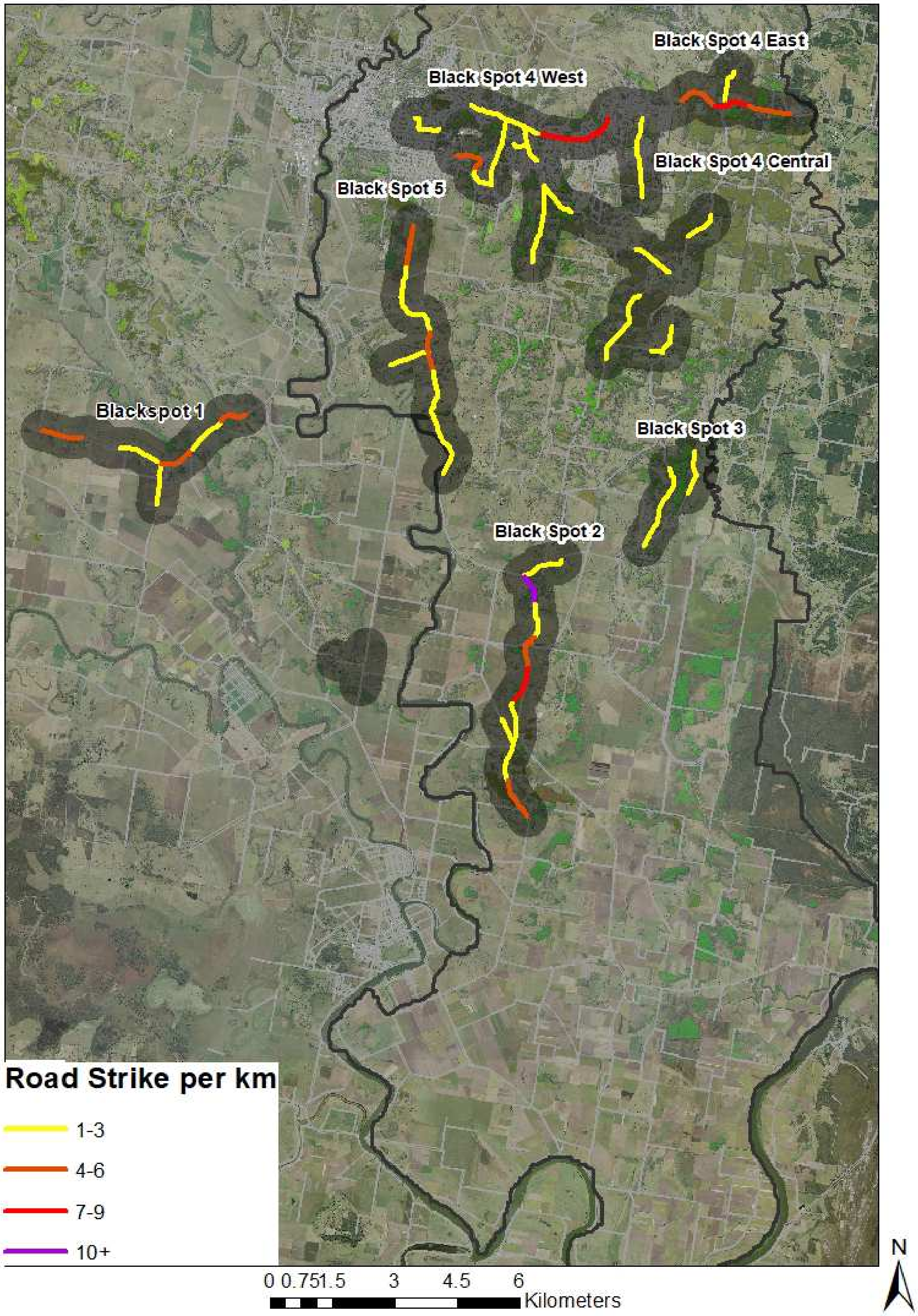

Figure 5: Locations of five black spots for koala vehicle-strike in the Lismore LGA (with correction for under-reporting on rural roads). Intensity of road strikes km^{-1} is indicated by colored lines.

Table 1: Details of the five black spots for koala vehicle-strike for the period 2011-2016 (L = length of black spot; *N* = numbers of vehicle-strikes). For ease of interpretation Black Spot 4 is divided into three sections; East, Central and West. * signifies a major black spot due to high numbers of strikes km^{-1}, either in a section of the black spot or in its entirety.

Black Spot No.	*L* (km)	*N*	Average numbers and range (in brackets) of vehicle-strikes km^{-1} $generation^{-1}$
1	6	17	2.8 (1 – 5)
2*	9	35	3.9 (1 – 12)
3	3	5	1.7 (1 – 3)
4 (East)*	4	19	4.8 (1 – 7)
4 (Central)	10	14	1.4 (1 -3)
4 (West)*	10	26	2.6 (1 -9)
5	8	19	2.4 (1 – 5)

By partitioning vehicle-strike data into the numbers of koalas being struck by vehicles km^{-1} $generation^{-1}$ it is possible to prioritize black spots for remedial action. Black spots that had an average number of road strikes km^{-1} $generation^{-1}$ ≥ 3.5 and / or sections of road within the Black Spot that had a strike rate of ≥ 9 road strikes km^{-1} $generation^{-1}$ were designated as 'Major Black Spots'. The remaining black spots were designated as 'Minor'. The former areas are discussed in more detail on the following pages.

MAJOR BLACK SPOTS

1. South Wyrallah Road (Black Spot 2, Figure 5): located rurally, along the southern part of Wyrallah Road, Tucki Road, Tuckurimba Road and Leslie Lane, Black Spot 2 is 9 km in length. There have been 35 known road strikes at this locality (average = 3.9 road strikes km^{-1} $generation^{-1}$). One section within this Black Spot, near the intersection of Wyrallah and Tucki Roads (Figure 6, highlighted in purple) represents the highest density of koala vehicle collisions within the LGA, with 12 koalas reported as being hit by cars over this 1 km stretch.

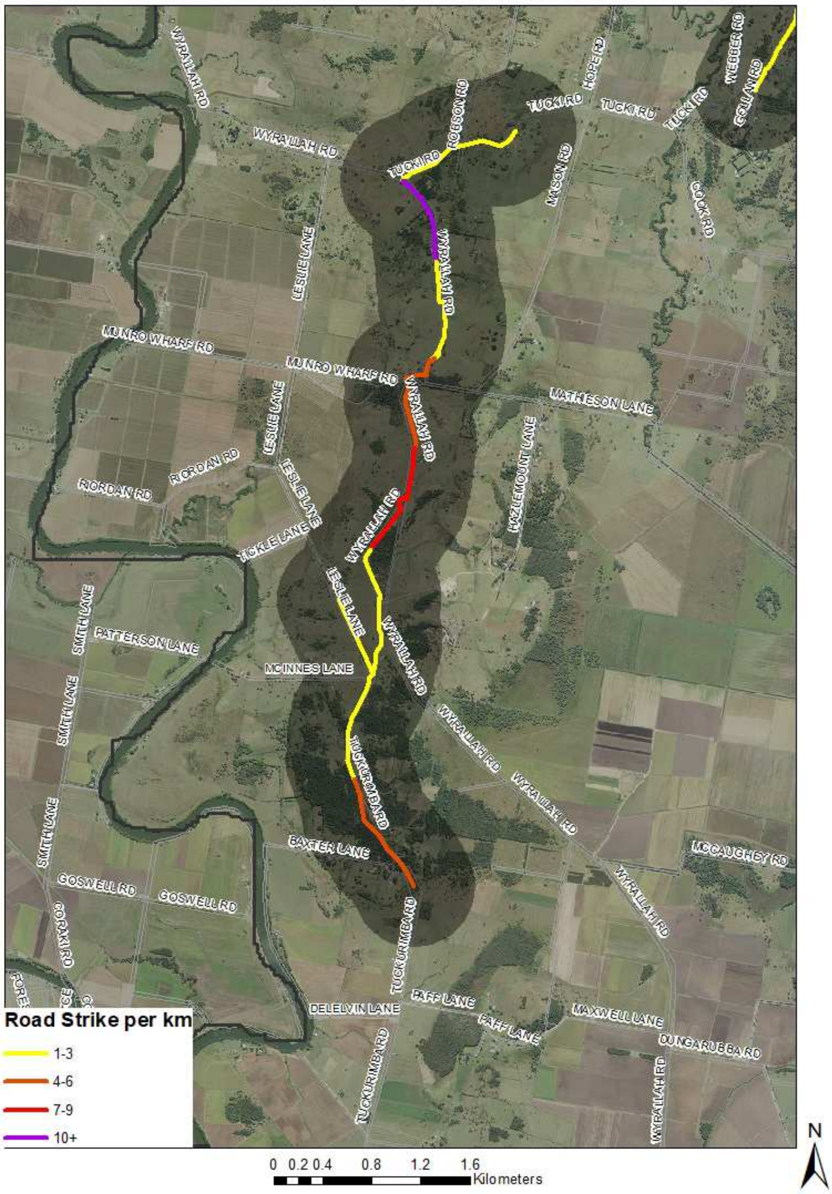

Figure 6: Black Spot 2 on southern Wyrallah Road, Tucki Road, Tuckurimba Road and Leslie Lane.

2. Bruxner Highway – Alphadale Road & Cowlong Road intersection (Black Spot 4 (East), Figure 7): In its entirety, Black Spot 4 consists of a network of 26 km of roads, not all of which are connected. For ease of interpretation, this area is considered in three sections; Black Spot (BS) 4 (East), (Central) and (West). BS 4 (East) is situated in a rural area where the Highway enters from the east, adjoining remnant native vegetation near the intersection of Alphadale Rd and Cowlong Roads with the Bruxner Highway. Covering 4 km of road and recording 19 koala-vehicle collisions, this Black Spot has the highest average number of road strikes km^{-1} $generation^{-1}$.

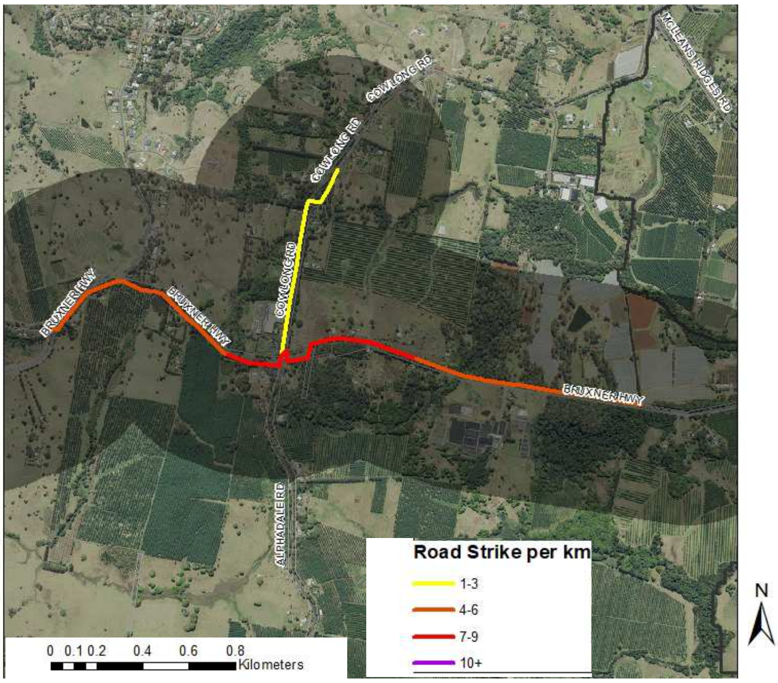

Figure 7: Black Spot 4 (East) on the Bruxner Highway and Cowlong Road where they intersect near Lindendale.

3. Bruxner Highway, Goonellabah (Black Spot 4 (West), Figure 8): Located in an urban area and following a stretch of highway running through Goonellabah and East Lismore from Pindari Crescent to Kellas Street, this black spot also includes sections of Rous Road, Pleasant Street, Invercauld Road, Kruseana Avenue, Cynthia Wilson Drive and a non-adjoining section comprising Ballina Road / Bruxner Highway and Hunter Street. Covering 10 km of roads and accounting for 26 koala road strikes over the previous koala generation, this black spot has an average number 2.6 road strikes km^{-1} $generation^{-1}$. Within this densely populated area, the highest intensity of road strikes is in the section of the Bruxner Highway from the Kadina intersection to Rous Road with 15 road strikes occurring over the most recent koala generation in a section of road less than 2 km in length.

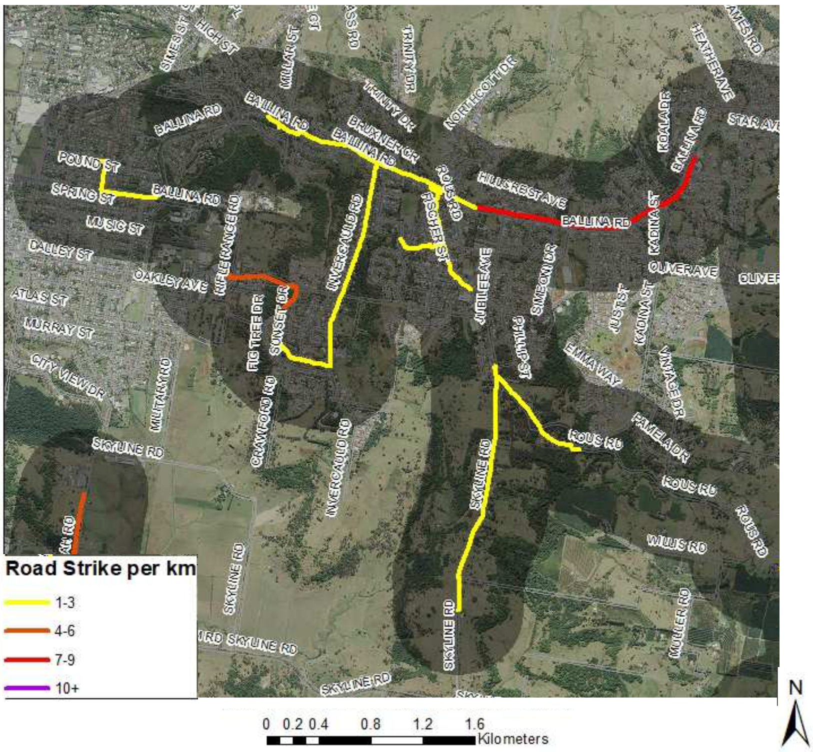

Figure 8: Black Spot 4 (West) comprises the Ballina Road / Bruxner Highway from Pindari Crescent to Kellas Street, and includes sections of Rous Road, Pleasant Street, Invercauld Road, Kruseana Avenue, Cynthia Wilson Drive and a non-adjoining section comprising Ballina Street / Bruxner Highway and Hunter Street. Note that a section of Skyline Road and adjoining Rous Road are also represented in this figure, but they are considered separately (as part of Black Spot 4 Central).

MINOR BLACK SPOTS

1. Black Spot 1: Located ~1 km west of the CKPoM area at the intersection of the Bruxner Highway and Tatham Road, this black spot covers 6 km of road and accounts for 17 koala vehicle collisions, the highest density taking place at the intersection itself. The average numbers of vehicle-strikes is 2.8 km^{-1} $generation^{-1}$
2. Black Spot 3: Situated rurally and running along Grennan and Graham Roads, south of Tregeagle, this black spot is 3 km in length averaging 1.7 vehicle- strikes km^{-1} $generation^{-1}$.
3. Black Spot 4 Central: Comprising Holland Street, Taylor Road, portions of Alphadale Road, Rous Road, O'Connor Road, Tregeagle Road and northern Skyline Road, this portion of Black Spot 4 is dispersed over a large area, extending south almost to Tregeagle and west to Southern Cross University and involving both urban and rural roads. Covering 10 km of roads, it has an average number of vehicle-strikes of 1.4 km^{-1} $generation^{-1}$
4. Black Spot 6: This black spot is located rurally along the northern portion of Wyrallah Road, commencing near the Waste Depot and extending south as far as Ferry Road. Eight kilometers in length, the average number of vehicle strikes is 2.4 km^{-1} $generation^{-1}$.

Dog Attack

There were 88 domestic dog attacks on koalas reported to FoK in the 2011-16 period, 75% of which (*n* = 66) were fatal. While reports of domestic dog attacks were widely distributed across the Lismore LGA, the highest densities occurred in urban areas of East Lismore that interface with bushland (Figure 9). While the number of dog attacks per year remained steady for most of the preceding koala generation, there was a significant spike in 2016 (Table 2). To determine whether the value from 2016 was a significant outlier we again performed Grubb's test, also known as the Extreme Studentised Deviate. This test indicated that the number of dog attacks in 2016 was indeed a significant outlier ($P<0.05$, two sided, Critical value of $Z = 1.9$). The locations of these 2016 attacks do not differ markedly from those of previous years (see Figure 8), the only distinction being increased attacks in the very north of the LGA near Nightcap National Park and to the south west, near Flood Reserve Road and Munro Wharf Road. Male koalas were over-represented in dog attacks (1.46 males: 1 female).

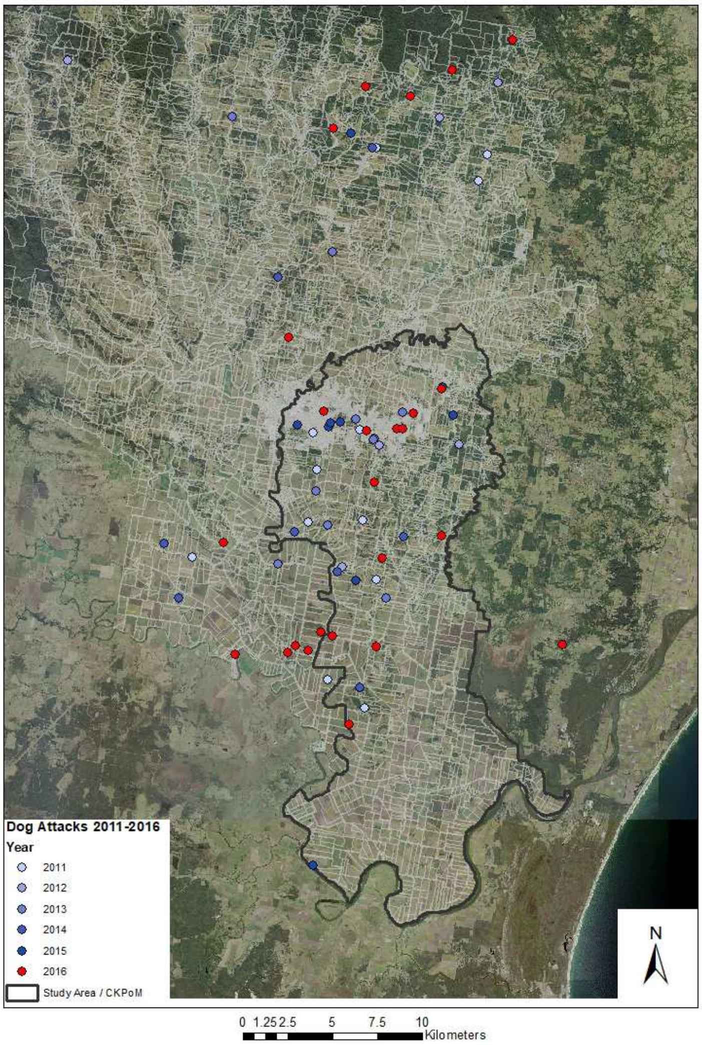

Figure 9: Location of domestic dog attacks reported to FoK 2011-2016 in the context of the CKPoM area (black) and the Lismore LGA (grey).

Table 2: Number of koalas reported to FoK as a result of domestic dog attack. * indicates that the value is a statistically significant outlier from other years (P<0.05), as indicated by Grubb's test.

Year	2011	2012	2013	2014	2015	2016
No. dog attacks reported to FoK	17	10	12	10	10	29*

Field Survey

Vegetation Mapping & Koala Habitat Categorisations

Seventy field sites were sampled. Forty-four of these field sites (*i.e.* ~ 63%) contained one or more tree species known to be preferentially utilised by koalas, specifically Tallowwood and/or Grey Gum and/or Swamp Mahogany and/or Forest Red Gum. This result implies that ~37% of the sampled woodland and/or forest cover currently categorised as PKH is not. Forest Red Gum – Tallowwood was the plant community most commonly mis-typed, this community comprising 38.5% (10/26) of sites not containing PKFTs. Appendix 1 provides a summary of the field survey data, including identification of localities where polygon mis-typing was assessed as most likely.

Koala presence at each field site, as evidenced by koala faecal pellets, was recorded at 33 of the 44 sites in which PKFTs were present and only at one of the 26 sites that did not have PKFTs. These data enables an estimate of habitat utilisation/occupancy by koalas across the study area of 77.3% ± 6.32% (SE) of available habitat. Figure 10 illustrates the overall distribution of field survey effort in terms of the presence / absence of both PKFTs and koala faecal pellets.

Lismore Koala Population Assessment 2017

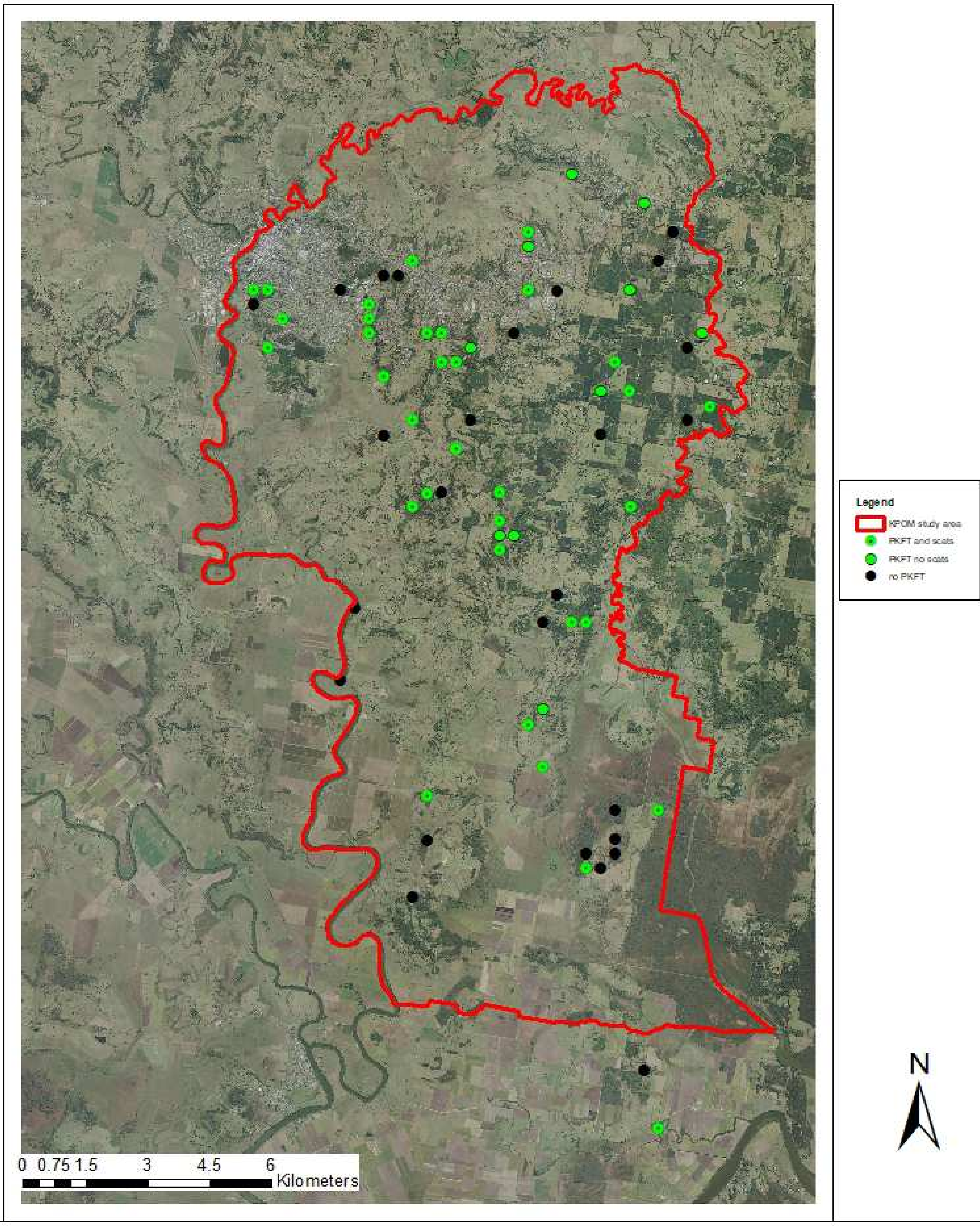

Figure 10. Field Survey Sites & Associated Outcomes

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Cartographic detail may not be accurate when used for survey purposes.

Date of Map: September, 2017

Koala Density

Five koalas were recorded in the 13.72 ha censused by the 25 m fixed-radius (0.196 ha) searches undertaken at each field site, while 19 koalas were recorded within the 61.64 ha of transect searches. These data result in density estimates of 0.36 ± 0.06 (SE) koala ha^{-1} and 0.31 ± 0.06 koalas ha^{-1} respectively. There was no significant difference between the two density estimates (Levene's Test $F = 3.34$, $P < 0.001$; $t = 0.413$, $P = 0.34$, 100_{df}).

To increase certainty around the density estimates and guided by the approach of Roberts and Binder (2009)[1] we pooled survey outcomes arising from the two survey methods to obtain a refined density estimate of the numbers of koalas ha^{-1} ($Ø_3$) as follows:

$$Ø_3 = (Ø_{n1} + Ø_{n2})/2 \qquad \text{(Eqn 1)}$$

Where:

$Ø_3$ = refined koala density estimate
$Ø_{n1}$ = density estimate from fixed-radius searches: 0.36 ± 0.06 (SE) koalas ha^{-1}
$Ø_{n2}$ = density estimate from transect searches: 0.31 ± 0.06 (SE) koalas ha^{-1}

with a Standard Deviation of:

$$\sigma = \sqrt{}(Ø_3 * (1-Ø_3)/((n_1 -1 + n_2 -1)/2) \qquad \text{(Eqn 2)}$$

Where:

σ = standard deviation of the refined estimate
$Ø_3$ = refined koala density estimate
n_1 = number of survey sites associated with $Ø_1$
n_2 = number of survey sites associated with $Ø_2$

The preceding approach results in a koala density estimate for the planning area of 0.34 koalas ha^{-1}. When extrapolated across the 5,273 ha of habitat currently mapped within the study area boundaries, this yields a koala population estimate for the study area of 1,766 ± 194 (95% CI).

Opportunistic sightings

Including results from direct count surveys, forty-one koalas (12M, 15F, 14 sex unknown) were observed during the survey. Koala sightings were most commonly associated with remnant vegetation patches (63.4%) but also wind-breaks and/or lines of trees within road reserves (26.8%), the remainder being observed in isolated paddock trees (9.8%). Koala joeys were observed on three

[1] Analyses based on combining similar information from multiple surveys. *Journal of Statistical Mechanics*. 2138 – 2147.

of the 13 adult females; this outcome should not be interpreted as an indication of the total numbers of breeding females because the presence of small(er) pouch-young remained unknown. More than half of these sightings (21/41) were restricted to a discrete area of approximately 1,600 ha located between Tregeagle, Wyrallah and Monaltrie. To the extent where it was readily apparent upon field observations, clinical signs of Chlamydiosis in the form of conjunctivitis and/or wet-bottom/dirty-tail were observed in 10 of the 41 koalas, three of which were sufficiently advanced to warrant notification to FoK. Figure 11 illustrates the distribution of koala sightings across the survey area.

Lismore Koala Population Assessment 2017

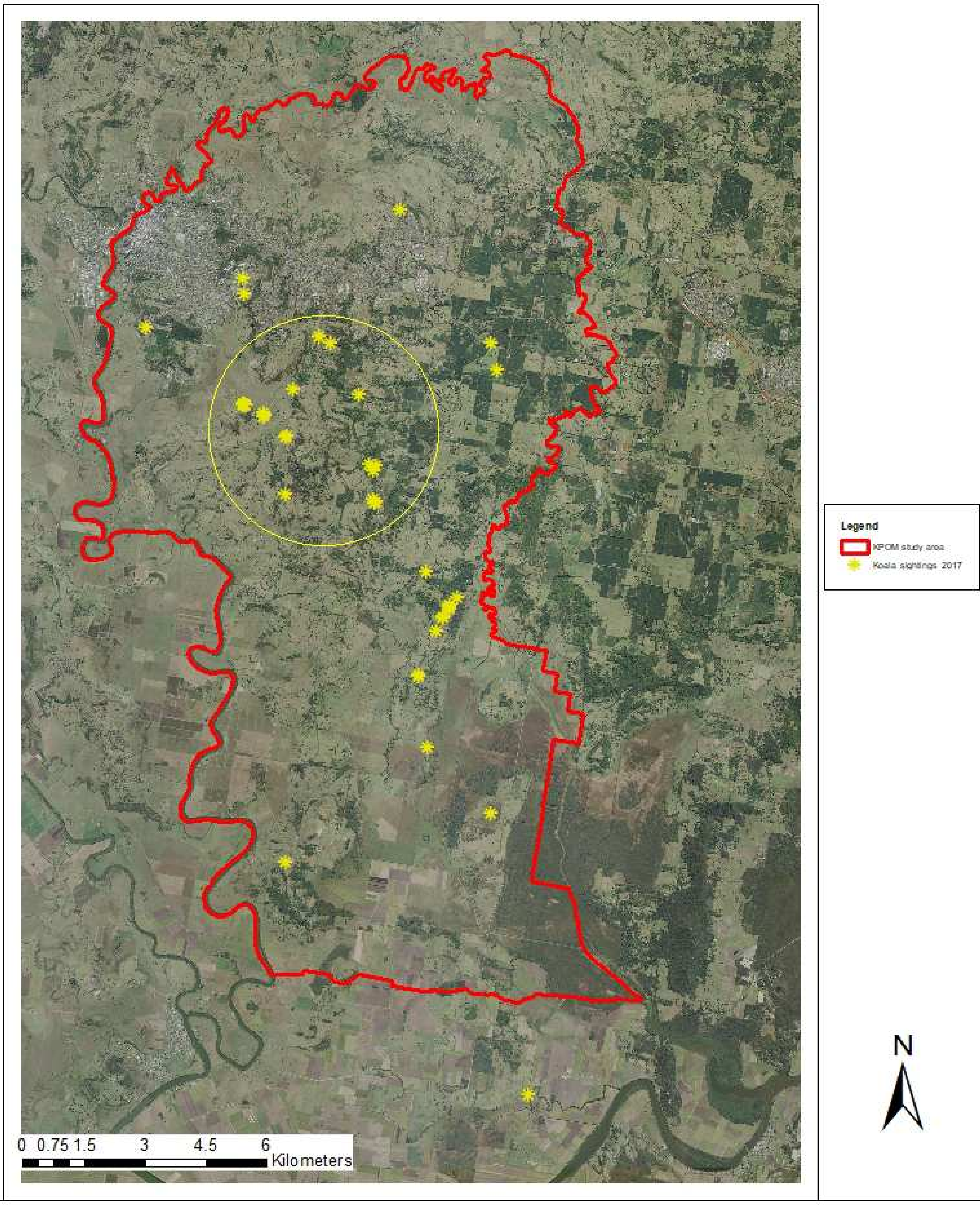

Figure 11. Opportunistic Koala Sightings

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Date of Map: September, 2017

Note: The location of a key local source population or hub in the general area between Tregeagle, Wyrallah and Monaltrie is approximated by a yellow circle.

Discussion

Records analysis confirms that koalas remain widely distributed across the LGA with no significant change in either of the key range parameters *Extent of Occurrence* and *Area of Occupancy* when compared to estimates for preceding koala generations.

Within the CKPoM planning area, our field-based measures of 0.34 koalas ha^{-1} and occupancy estimates for the current koala generation in the range of 50% - 77% of available habitat are the highest we have recorded from coastal LGAs between the Tweed and Clarence Rivers (Biolink, 2010; Biolink, 2011; Biolink 2012; Biolink 2015). Indeed and when considered in the context of an estimated population size of approximately 1,800 koalas, these outcomes collectively imply optimal occupancy rates and a landscape that is close to or already at peak carrying capacity. If this is true, then it is likely that future sampling events will confirm either a plateau in koala numbers, or potentially a decline as equilibrium is reached with the environment. Regardless, the outcomes from this study are of considerable interest in terms of koala conservation biology given widespread declines elsewhere throughout the species' remaining range in eastern Australia. The reasons behind the historical and ongoing range expansion of koalas in both the Dorroughby – Dunoon – Rosebank and CKPoM planning areas in particular thus warrant further investigation and documentation.

Despite the fact that koalas are widespread across the CKPoM planning area and the Lismore LGA in general, their distribution remains fragmented by agriculture and urbanisation. Assessing connectivity across such a landscape can be problematic when population disjunction is occurring at a fine scale, as it is here. Given that the current koala population within the CKPoM planning area appears relatively stable, this suggests that connectivity, or lack thereof, is not a pressing concern. The aim therefore should be to sustain a landscape in which agriculture, people and koalas can co-exist. This can be achieved by ensuring that the terrain remains permeable to koala movement by securing known source populations and their associated habitat patches while retaining and increasing the numbers of PKFTs across the landscape in such areas to provide greater connectivity (McAlpine *et al.*, 2007; Beier *et al.*, 2008). An ability to move freely across the landscape allows dispersal and continued contact between sub-populations. This permits the maintenance and regulation of existing populations, the establishment of new populations and preserves a given population's capacity to respond to change.

Threatening Processes

Disease

Disease-mediated koala mortality across the Lismore LGA remains at high levels, accounting for 50% of known mortalities recorded by FoK. While highlighting the importance of disease management as a local issue, a continuing trend of population stability is revealed by both records analysis and field survey, the latter revealing a high density of koalas occupying a substantive portion of the habitat currently available to them. Given high disease rates yet strong indicators of population stability, disease *per se* appears at this point in time (somewhat counter-intuitively) to not be an overriding threat to long-term koala viability in the CKPoM planning area. Disease arguably represents a symptomatic rather than causal issue affecting koala population viability and its association with low genetic diversity, a feature of the Lismore and Tyagarah koala populations (Lee *et al*. 2013; Phillips 2017), further necessitates a nuanced consideration of the implications of disease generally. New alleles currently moving into the CKPoM planning area from the north will increase the genetic diversity of Lismore koalas in the long term, arguably improving their immunological fitness. However, the association between disease, population density and the carrying capacity of the environment make this association complex; it is also possible that local koala populations are at a point whereby they have currently overshot the optimal occupancy rate of available habitat and the high density of animals in many areas may also be exacerbating disease prevalence.

Vehicle-strike and Dog Attack

Anthropogenic mortality drivers, specifically domestic dog attack and vehicle-strike, have the capacity to negatively influence longer-term population viability. Mortalities due to cars and domestic dog attacks account for one quarter of all known mortalities across the Lismore LGA and the location of these incidents is reflective of koala movement patterns. Previous studies have also found that a high proportion of the mortality of dispersing koalas is associated with attacks by domestic dogs and vehicle-strike (Dique *et al*., 2003).

Predicting areas where koalas are most likely to cross roads is an important first step in mitigating from the issue of vehicle-strike. The number of koalas being killed within the CKPoM planning area has been increasing annually since at least 1998 (Figure 3 refers) and occur in consistent and readily identifiable localities (Figure 4 refers). Wyrallah Road, between southern Lismore and Tuckurimba was reported as the area where the highest density of koala road kill was occurring in previous generations (Biolink 2011) and the Bruxner Highway between Lismore and Alstonville was the next highest contributor to koala road-kills in previous koala generations, as it is here. These are persistent issues that remain to be rectified.

The analyses in the current report are informative in terms of the spatial distribution of road strikes. Effective solutions to the identified black spots must be tailored to the individual characteristics of the black spots themselves. The probability of animal-vehicle collision increases exponentially with traffic volume (Klöcker *et al*., 2006) but there are many additional variables to consider, such as the cover and quality of roadside vegetation, local road characteristics and the density of animals along the road. It is noteworthy that the high density of vehicle-strikes along the Kadina Street to Rous Road section of the Bruxner Highway corresponds directly with a portion of the Highway where the road corridor is offset such that a traffic island in the center is raised on one side more than the other, creating a wall. This barrier is impassable to koalas, preventing them from completing a road crossing. Presumably koalas either turn back upon encountering the barrier or continue along the road in search of a location to cross, during which time they become vulnerable to vehicle-strike in larger numbers (Phillips and Fitzgerald 2015). The installation of two-way koala bridges, in the form of climbable poles, at intervals along this section of highway may help to ameliorate the problem by allowing koalas to complete their intended road crossing.

Black Spot 4 (East) will require a different approach to vehicle-strike mitigation. This area traverses a large stand of mature Tallowwoods. In this instance, the installation of exclusion fencing and strategically placed underpasses, along with signage, is likely to be the more effective approach to reducing koala mortality. The third major black spot (Black Spot 2) presents an anomaly as it does not occur in an area of PKH, neither is there anything obvious about the conditions of the road itself that suggests that this should be an inherently dangerous road crossing. The presence of a wind-row of PKFTs near the intersection of Wyrallah and Tucki Roads, in an area with very few other koala food trees, may be contributing to the problem. It is also noted that this location, and indeed the great majority of roads with high intensities of koala vehicle strikes, involve intersections. Thought needs to be given as to why intersections present such a danger to koalas.

As evidenced by the paucity of vehicle-strikes in an otherwise high-density koala area, the protective measures enacted as part of the Skyline Road upgrade, including exclusion fencing, underpasses and the use of specifically designed koala-grids at fence ends and driveways, continue to prove effective in ameliorating koala vehicle-strike mortalities in this locality and so provide a benchmark for future road upgrades through areas of koala habitat. In the course of conducting field surveys detailed herein, an unsolicited account of high density of koalas was noted in this area by field staff; however, there was only one recorded mortality within the exclusion zone for the 2011-2016 period.

Community engagement indicates that this singular mortality may be reflective of maintenance issues of the exclusion zone itself.

Both dog attack and vehicle-strike data are indicative of the areas within human dominated landscapes which koalas are traversing to move between patches of desirable habitat. While collectively revealing about koala movement patterns, these threats need to be approached separately from a management perspective. Domestic dog attack continues to be a threat to koala populations and given that these attacks tend to occur at the interface of urban and bushland areas, the impact of dog attack will likely increase with further urbanisation and subsequent habitat fragmentation.

Habitat Management

While the total koala population within the CKPoM is large, this is due to a high density of animals occupying the available habitat. The available habitat itself is likely to be in the order of 3,500 ha, which is lower than the 5,200 ha otherwise indicated by available mapping. This arguably makes the koala populations within the CKPoM planning area more sensitive to habitat loss and modification than a population of comparable size which is less densely occupying a larger amount of habitat. Effectively preserving and managing habitat in the location of likely koala population hub located in the area between Tregeagle, Wyrallah and Monaltrie should be *a priori* consideration in the context of long-term sustainable management of koalas in the planning area.

Recommendations

Based on the preceding discussion the following recommendations are proposed:

1. The technique employed to assess rates of koala occupancy in this survey is an efficient means of establishing koala presence/absence. We recommend continuing to use this methodology for repeated monitoring of the established sites to address changes in the utilisation/occupancy rate of koala habitat, which in turn reflects fluctuations in the configuration and dynamics of local populations.
2. Ideally, the monitoring referred to in 1 above should be undertaken every two years, supported by a review of historical records at every third monitoring event. We thus recommend a future site-based monitoring events for the CKPoM planning area be scheduled for 2019, 2021 and 2023, with a review of historical records scheduled for 2023.

3. If future monitoring events evidence a reduction in koala habitat utilisation / occupancy to less than 40% of the available habitat for two consecutive monitoring events, this should trigger a review of the CKPoM and a re-assessment of threatening processes.
4. Site-based monitoring should include only those sites assessed in the current study that contained PKFTs, and should aim to recruit additional field sites from those initially identified for sampling. To ensure efficient use of resources, if landholders give approval to begin this process then an initial inspection of the site would identify whether it includes PKFTs, given the proportion of field sites in the current study which were found to be unsuitable.
5. Rural landholders should be actively encouraged to plant and maintain PKFTs, to keep the landscape amenable to koala movement and ensure the linkage of populations. Wind-breaks can be an excellent resource for koalas and the tree species preferred by koalas are well suited to this purpose.
6. In addition to documenting an ecological history of koalas and their habitat across the LGA, Council should seek to more accurately establish the full extent of the Tregeagle – Wyrallah - Monaltrie koala hub, including the promulgation of hub-specific planning measures to ensure long-term sustainable management of habitat therein and associated resident koala populations.
7. Council should seek funding to address major black spots for vehicle-strike. Ideally this will include an assessment of each of the major black spots identified in this report, such that the black spot is examined individually with mitigation plans tailored to the unique threats and topographical features of the area itself. This should also include a review of vehicle traffic data to inform an understanding of vehicle loads and movements to ascertain whether increased traffic, or higher densities of koalas, or both, is responsible for the rates of vehicle-strike. Mitigation strategies may require the application of new technologies, such as Wildlife Activated Signage. As evidenced by the absence of vehicle-strike data arising from the 2007 Skyline Road upgrade, the effectiveness of black-spot mitigation approaches can be determined during monitoring events that include records analysis (which occurs once every koala generation).
8. A high profile, ongoing and direct engagement with the community regarding dog attacks is also required, focusing on those areas with the highest incidence of this activity. This should include an active educational campaign promoting responsible dog ownership within the LGA and information provided specifically to residents in areas identified as dog attack centers.

9. Work to improve Council maps of PKH. This could initially be addressed by including information from Appendix 1 regarding the presence or absence of PKFTs at the 70 surveyed sites, with the aim to extend this with data from additional landholders as it becomes available.

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Appendix 1

Details of the 70 field sites sampled for purposes of the 2017 survey. Thirty-four sites contained evidence of koala activity. Sites located within mapped polygons considered likely to be incorrectly typed are bolded.

Site No.	Easting	Northing	Koala Activity	PKFTs
LIS050	529588	6811731	yes	yes
LIS085	529576	6811033	yes	yes
LIS009	529576	6811380	yes	yes
LIS125	**528878**	**6812081**	yes	no
LIS095	530633	6812782	yes	yes
LIS107	**529916**	**6812423**	no	no
LIS084	**530280**	**6812439**	no	no
LIS096	527468	6811377	yes	yes
LIS097	**526782**	**6811732**	no	no
LIS031	526789	6812076	yes	yes
LIS051	527116	6812082	yes	yes
LIS111	530968	6811039	yes	yes
LIS112	531337	6811037	yes	yes
LIS045	**533067**	**6811031**	no	no
LIS094	533416	6812088	yes	yes
LIS049	**534131**	**6812064**	no	no
LIS048	533422	6813484	yes	yes
LIS030	533411	6813136	no	yes
LIS010	531316	6810336	yes	yes
LIS054	531668	6810325	yes	yes
LIS056	**529921**	**6808568**	no	no

Site No.	Easting	Northing	Active 2017	PKFTs
LIS103	532017	6810684	no	yes
LIS068	**533775**	**6804024**	no	no
LIS029	534460	6814874	no	yes
LIS027	**536913**	**6813476**	no	no
LIS098	527134	6810690	yes	yes
LIS123	531667	6808223	yes	yes
LIS058	**531324**	**6807186**	no	no
LIS053	529924	6809972	yes	yes
LIS101	530632	6808929	no	yes
LIS110	532716	6806475	yes	yes
LIS061	**535175**	**6808572**	no	no
LIS086	**532028**	**6808933**	no	no
LIS121	532717	6807173	yes	yes
LIS106	535176	6809623	no	yes
LIS102	535869	6809629	yes	yes
LIS126	535868	6812080	no	yes
LIS113	535530	6810330	yes	yes
LIS069	**537266**	**6808937**	no	no
LIS109	533431	6801563	yes	yes
LIS005	533783	6801928	no	yes
LIS077	534813	6804042	yes	yes
LIS108	534472	6804038	yes	yes
LIS090	**534116**	**6804718**	no	no
LIS024	532712	6805787	yes	yes
LIS070	**536580**	**6812778**	no	no
LIS080	**537264**	**6810674**	no	no
LIS073	530976	6799833	yes	yes
LIS060	**530622**	**6797380**	no	no

Site No.	Easting	Northing	Active 2017	PKFTs
LIS032	**529222**	**6804376**	no	no
LIS074	**528878**	**6802636**	no	no
LIS117	530963	6798774	no	no
LIS022	533783	6800543	yes	yes
LIS023	535886	6806822	yes	yes
LIS002	536553	6799484	yes	yes
LIS019	534827	6798086	yes	yes
LIS037	**535511**	**6798426**	no	no
LIS021	**534824**	**6798431**	no	no
LIS065	**535529**	**6798779**	no	no
LIS020	**535167**	**6798089**	no	no
LIS004	**535517**	**6799480**	no	no
LIS017	**536229**	**6793180**	no	no
LIS076	536559	6791785	yes	yes
LIS014	530616	6806827	yes	yes
LIS057	530981	6807167	yes	yes
LIS046	537634	6811033	no	yes
LIS105	537820	6809270	yes	yes
LIS042	533076	6806143	no	yes
LIS025	532716	6806142	no	yes
LIS062	536230	6814194	no	yes