Proposed Expansion of the Brandy Hill Quarry:

Habitat Utilisation by Koalas

Report to Department of Agriculture, Water & the Environment

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Table of Contents

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Acronyms used in this report

Abbreviation	Description
AoO	Area of Occupancy
ARKS	Area of Regional Koala Significance
DBH	Diameter at Breast Height
DoE	(former) Commonwealth Department of Environment
EoO	Extent of Occurrence
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
GPS	Global Positioning System
KHSM	Koala Habitat Suitability Model
LGA	Local Government Area
LoDA	Limit of Disturbance Area
MNES	Matter of National Environmental Significance
NSW	New South Wales
PCT	Plant Community Type
PS	Port Stephens
PKFT	Preferred Koala Food Tree
SAT	Spot Assessment Technique
SE	Standard Error
TSSC	Threatened Species Scientific Committee
UTM	Universal Transverse Mercator

Summary

This report focuses on an assessment of koala distribution, abundance, and activity over an area of approximately 640 ha (the study site) located off the Clarence Town Road between Seaham and Woodville in the Port Stephens Local Government Area (PSLGA). The focal area within the study site was the Brandy Hill quarry, at which there is a proposal to expand the quarry footprint. The Limit of Disturbance Area (LoDA) envisioned by the proposed expansion will result in the removal of ~ 53 ha of native vegetation, and the matter has become a controlled action for purposes of the EPBC Act because of the potential impact on koalas.

Contemporary studies have identified a strong recovery trend by koalas in western parts of the PSLGA. For this project, an updated review of available records within a 10 km radius of the quarry site confirms that the ongoing recovery trend has now manifested itself in identifiable areas of generational persistence (*i.e*. one or more records for each of the three most recent koala generations) occurring over the immediately adjoining 1,600 ha (4 x 400 ha grid cells) proximal to the quarry site, as well as a further 1,600 ha around the localities of Duns Creek and Glen Oak to the north. The recovery trend is also resulting in an escalating frequency of domestic dog attacks on koalas and occasional koala vehicle-strikes along the Clarence Town Road between Seaham and Woodville.

Field survey was based on the application of Spot Assessment Technique (SAT) protocols at 500 m intervals across the study site, increasing to ~ 350 m intervals within the LoDA. Field survey detected evidence of habitat use by koalas at 9 of 26 primary field sites that were assessed, with SAT-derived koala activity levels in active sites ranging from 3.33% – 33.33%. Koala activity levels were modelled using thin-plate regularised splining, a mathematical process enabling gradients between series of spatially separated data points to be identified through interpolation. Subsequent contouring of splining output using applicable SAT activity thresholds resulted in three areas of significant koala activity being delineated within the study site, the first covering an area of ~ 50 ha located in the southwestern corner and thereafter extending to the west and southwest into adjoining properties, the second more centrally located towards the southern edge of study site east of the quarry entrance road and extending to the south across Clarence Town Road, and the third a smaller area immediately adjoining the southern quarry / bushland interface. This latter area was also identified in the earlier assessment by Biosis; however and while we have taken a precautionary approach and attributed this particular activity cell to koalas, it is reasoned on the basis of modelling output, scat anomalies, and spotlighting results, that the data from this area more likely reflects activity of Brush-tailed Possums, rather than koalas.

Replicated spotlighting transect searches covering a linear distance of 7.85 km / ~ 28.9 ha were also undertaken through the LoDA and elsewhere across the study site over 3 non-consecutive nights. Spotlighting did not visually detect any koalas, but calling males were heard beyond transect search parameters on two nights, one of which, a young male, was subsequently located following a further spotlight search in the general area it was initially heard calling from.

Spotlighting data was in agreement with the independently derived SAT data obtained by this study in terms of confirming that the greater proportion of the study site does not currently support resident koala population cells, instead being the subject of Low (transient) use. This is a positive outcome because it foretells of increasing occupancy potential in higher habitat quality areas of the site in the relatively near future, while also implying that any impact arising from the removal of native vegetation from the LoDA can be managed without a significant impact on koalas being manifested. To this end and at this point in time, spotlighting data implies that koala density across the site will arguably be less than 0.03 koalas $ha^{-1,}$ which in turn implies an estimated population size of < 18 koalas within the 640 ha of the study site, and at best, no more than 1 - 2 within the LoDA. This result is lower than the 0.05 koalas ha^{-1} we have recorded from similar habitat types in the Kings Hill and Grahamstown Dam areas to the east, and contrasts strongly with 0.34 koalas ha^{-1} recorded from higher quality habitat areas elsewhere in the PSLGA at locations such as Anna Bay – Soldier's Point.

A four-tiered koala habitat classification was applied to the site based on 25 ha grid cells that result from the 500 m sampling interval, thereafter informed by tree species, relative abundance and associated metric data collected by the SAT. Amongst other things, these data indicate that Preferred Koala Food Trees (PKFTs) > 300 mm DBH are sparsely distributed across the study site, and that Plant Community Types therein are primarily comprised of low carrying capacity Secondary (Class C)/Marginal) and to a lesser extent Secondary (Class B) koala habitat categories. This outcome is at odds with that predicted for the site by the NSW Government's Koala Habitat Information Base, and specifically the Koala Habitat Suitability Model (KHSM). Reasons for this disparity include the underlying assumptions and limited ground truthing that underpins the KHSM, while and amongst other things, the Koala Tree Index that it is additionally reliant on is qualitatively informed and hence overstates the importance of most areas to koalas. As demonstrated by this study, reliance upon the mapping layers and indexes of the KHSM when used without regard for local site-specific data/knowledge will invariably misrepresent the importance of many areas at both ends of the koala habitat quality spectrum.

The absence of koala occupancy and significant activity data from the greater proportion of the study site presents a challenge in terms of considering matters of connectivity at a site-based scale. More elevated portions of the study site (*i.e*. upper slopes and ridgelines) are also notable for extensive areas of dieback, the causes of which do not appear to be fire-related but rather the result of protracted historical water stresses that have resulted in leaf fall and tree mortality; recovery is progressing slowly in some areas, but widespread tree deaths, including PKFTs, have resulted in both the LoDA and elsewhere across the study site. In contrast, lower elevations of the study site tend to exhibit less dieback and significantly higher measures of tree health, as measured by comparative analyses of tree girth. For these reasons and with regard to a future of increasing climatic uncertainty, we consider that the lower elevation (southern) parts of the site offer greater potential for koala occupancy and/or habitat connectivity consolidation, than do areas in the north. Removal of native vegetation from the southern end of the LoDA has the potential to negatively impact on current east-west connectivity considerations for koalas. However, we consider that this can be managed in a meaningful way through on-site offsetting and habitat rehabilitation measures.

Given the above and in addition to a staged and monitored removal of vegetation from within the proposed LoDA footprint, we further advocate consideration of on-site offsetting in lower-lying areas of the site as part of any ameliorative measures associated with approval of the quarry expansion. This approach is supported by earlier connectivity modelling across the PSLGA which independently identified several 'least-cost' dispersal pathways at the southern end of the study site, so named because they represent the most ecologically efficient means for a given species, in this case the koala, to move between patches of preferred habitat. Additionally, the lower strata in some areas of the study site are dominated by dense thickets of Lantana which can work to the detriment of native plant community vitality by sequestering otherwise limited nutrients such as water. Hence enactment of an assertive on-site habitat restoration plan achieved through active weed management in areas so affected should also be considered as part of any pro-active management response.

1. Introduction

Koalas have a long and enduring history across the Port Stephens (PS) Local Government Area (LGA) and despite a significant decline in occupancy east of the Pacific Highway (Biolink 2016), a later field survey estimated a naïve[1] occupancy rate of 39.5% ± 7.5% (SE) of the available koala habitat across the entire PSLGA (Biolink 2017), while estimating the total population size of koalas therein at ~ 1,200 individuals (Biolink 2017). Examination of historical records additionally identified several potential koala population hubs across the PSLGA, including one in the general area of Brandy Hill, southwest of Seaham (Biolink 2017, 2018b).

The koala was listed as Vulnerable in NSW, Queensland and the Australian Capital Territory in 2012 for the purposes of the Commonwealth Government's *Environment Protection and Biodiversity Conservation* (EPBC) *Act 1999*, and in this context any negative impact on the species is considered a potential controlled action requiring referral to the Australian Government as a Matter of National Environmental Significance (MNES). A bilateral agreement has been approved between the Commonwealth and State government agencies, such that NSW processes are accredited under the EPBC Act for assessing proposed actions that are likely to have a significant impact on a MNES. Habitat loss, fragmentation and vehicle-strike are among the threats identified in the EPBC Act referral guidelines (DoE 2014) and the Threatened Species Scientific Committee listing conservation advice for the koala (TSSC 2011) as contributing factors driving population decline.

On top of a progressive attrition of koala occupancy in western parts of the koala's range in Eastern Australia, the 2019/20 fire season resulted in the additional loss of thousands of koalas from many areas along the east coast and Tableland areas of NSW (Lane *et al*. 2020), the scale of loss in all instances considered sufficient to warrant preparation of a nomination to the NSW Scientific Committee seeking an up-listing of the koala from Vulnerable to Endangered. Follow up research has offered some insight into the scale of impact on koalas, Phillips *et al.* (in press) reported a *post*-fire median reduction of 72% (range 34% - 100%) across six fire grounds when changes in habitat use were standardised against *pre*-fire utilisation levels. Importantly, evidence of koala survival was recorded from 5 of the 6 fire grounds that were surveyed, and koala survival was five times more likely in areas where the canopy was unburnt or only partially burnt; thus enabling recovery to occur in most areas, conditional upon size of the remaining population and future inter-fire intervals (Phillips *et al.,* in press). This knowledge, regardless of any final determinations as to conservation

[1] This term implies presence at a given area / site without regard for residency.

status, implies the potential for recovery pursuant to application of well informed, prudent approaches to koala management in areas where fire impacts have been less severe and/or viable populations remain *post*-fire. Fortuitously, forested areas west of the Pacific Highway in the PSLGA were largely spared from bushfire season and thus remain one of several known koala populations in NSW within which *pre*-fire population trends have remained uninterrupted.

Based on advice from the Independent Planning Commission (Duncan *et al*. 2020), in July 2020 the NSW Government approved expansion of activities at the Brandy Hill quarry located to the west of Raymond Terrace in the PSLGA. An earlier ecological assessment of the site in 2014/15 reported by Biosis (2016) identified the presence of koalas on site; it was subsequently considered that the proposed expansion had the potential for a significant impact on listed threatened species, including the koala, and the matter was referred to the Commonwealth for consideration as a controlled action. In the intervening period, community concern about the potential impacts of expanded quarrying operations on koalas became apparent, fuelled in part by sightings of breeding koalas in the general area surrounding the quarry, and the broader impacts of the 2019/20 bushfire season. A commissioned desktop review by Witt and Clulow (2020) also raised concerns about the potential impacts of the quarry expansion. Against this background and given concerns about the time that had elapsed since the initial koala work was undertaken, a further assessment of the quarry site was undertaken.

Report Scope and Objectives

The outcomes of this report arise from a Scope of Works provided by the Commonwealth Department of Agriculture, Water, and the Environment (DAWE) which required the following matters to be addressed:

1. an estimate of the carrying capacity and density of Koalas in the vegetation in the Limit of Disturbance Area (LoDA) to be cleared by the proposed development (See Limit of Disturbance Area at Annexure 1, approx. 52 hectares of koala habitat).
2. an estimate of the carrying capacity and density of Koalas across the Site (approx. 643 hectares).
3. an understanding of Koala movement corridors at the Site, particularly, north-south through the broader patch of remnant vegetation in the region, and east-west across the LoDA (see Figure 2, Expert Opinion Report prepared by Witt and Clulow of Newcastle University, dated 2 September 2020).

4. Records analysis/collation (*e.g*. NSW Bionet, Atlas of Living Australia, mapped habitat areas and community records) and analysis over a 50 km radius of the Site.

    4.1. To obtain community records and data, liaison with Dr. Ryan Witt of Newcastle University and/or the community organisation “Save Port Stephens Koalas”.

5. Surveys must use best practice techniques and include, but not be limited to:

    5.1. Surveys of the Site using full SATs (Grid-SAT approach) at 500 m intervals at approximately 15 to 20 sites.

    5.2. Surveys of the identified Limit of Disturbance Area at 350 m intervals at approximately four to five sites.

    5.3. Transect based spotlighting over a minimum of three non-consecutive nights to obtain density data for Koala.

6. A Report detailing data, findings, and results of the above which includes any figures and GIS files, survey locations, records and modelling undertaken.

In addressing the preceding matters, the report is also to include, but not be limited to:

    6.1. Identification and analysis of Koala movement corridors.

    6.2. An explanation of why the SAT technique, spotlight technique and other techniques you have used are appropriate and best practice for this species/site.

    6.3. Based on survey results, comment on the findings identified in the Expert Opinion Report prepared by Witt and Clulow of Newcastle University, dated 2 September 2020, including the analysis of a movement corridor based on the Koala Habitat Suitability Model used in that report and analysis of the relative value (like for like of the biobanking sites to the north of the Site).

    6.4. Based on survey results, any recommendations, including mitigation measures, which could reasonably be applied to complement or strengthen existing mitigation measures to reduce impacts of the proposed quarry expansion on Koala. Provide weighting or prioritise given the level of impact.

    6.5. Broader population estimate within the 50 km x 50 km radius of the Site.

    6.6. Expert opinion of the suitability of the biobanking offset sites to the north of the Site as being suitable like-for-like offsets to compensate for clearing in the LoDA.

2. Methods

a) Study Area

The study area comprised ~ 650 ha of land located off Clarence Town Road to the west of the village of Seaham which is approximately 12 km north of Raymond Terrace (**Figure 1**). Within this area it is proposed to expand the quarry footprint in a westerly and southerly direction, the realisation of which will require removal of approximately 53 ha of native vegetation, otherwise defined as the Limit of Disturbance Area (LoDA). Based on mapping prepared for purposes of the EIS, the LoDA and immediately surrounding areas comprising the study area supports several Plant Community Types (PCTs) that contain Preferred Koala Food Tree (PKFT) species Grey Gum *E. punctata*[2], Grey Box *E. moluccana* and Forest Red Gum *E. tereticornis* to varying degrees.

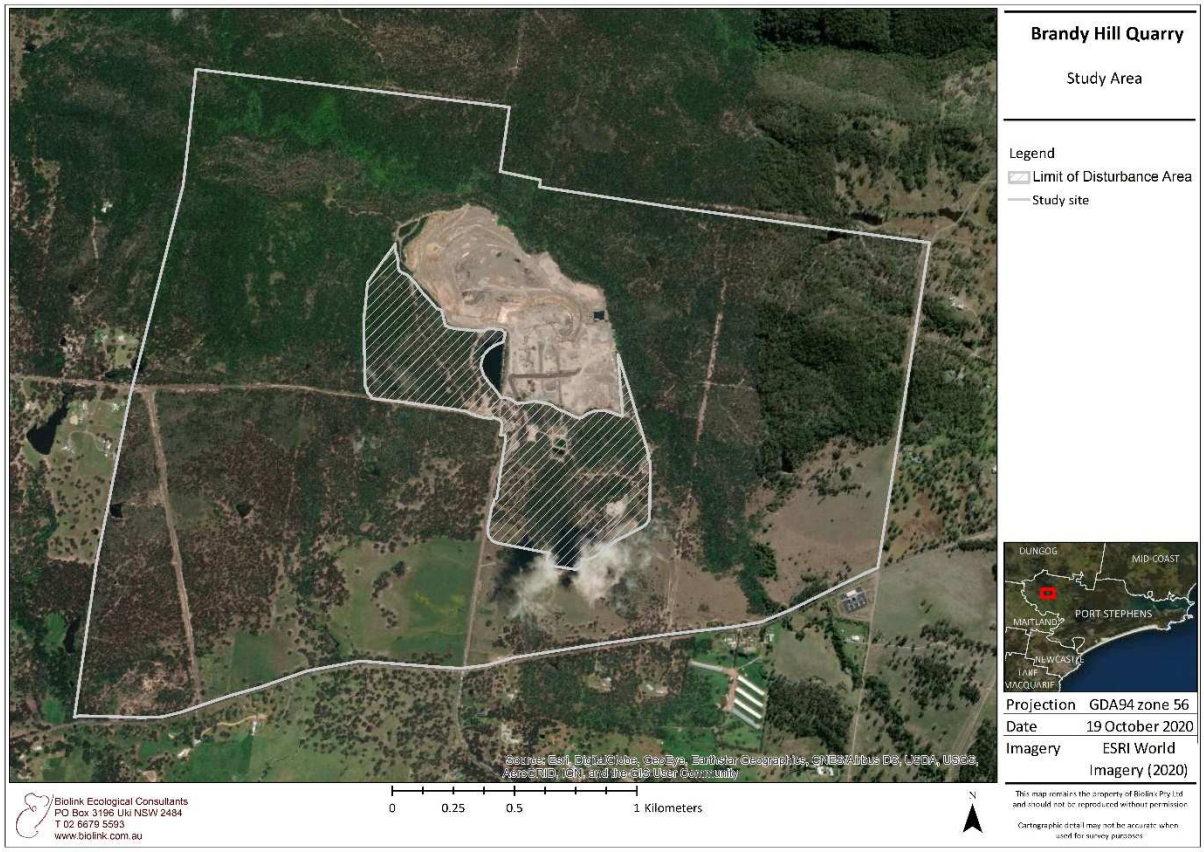

Figure 1. The Brandy Hill quarry property / study area (white boundary). The proposed Limit of Disturbance Area (LoDA) is the diagonally crossed area beyond the southwestern and southern boundaries of the quarry pit.

[2] Includes closely allied species *E. propinqua* and *E. canaliculata*.

b) Analyses of historical koala records

An earlier project (Biolink 2016) used 7,769 historical koala records from the NSW BioNet (Wildlife Atlas) and Hunter Wildlife Preservation Society (now Port Stephens Koalas) databases to and amongst other things, investigate changes in the range parameters Extent of Occurrence (EoO) and Area of Occupancy (AoO) of koalas across the PSLGA. Analyses revealed no significant change in the EoO over time across the PSLGA but did identify a statistically significant reduction in the AoO east of the Pacific Highway, and a significant increase in the AoO west of the Pacific Highway.

For this project, we did not consider changes to range parameters EoO and AoO at LGA level to be particularly useful beyond broad description given the localised area of interest. Instead, we focused our attention to records-induced changes within a 10 km radius of the LoDA. This approach enabled us to maximise the value of community-based records that were provided to us, but which were not otherwise in the public domain, while also ensuring that our analyses was targeted at the appropriate scale. We used these records in two ways; where we could determine accuracy to within 100 m, we determined Universal Transverse Mercator (UTM) site coordinates and uploaded such records and associated data into our larger spatial dataset, while ancillary information provided insights into presence of important population cohorts such as breeding females, and the existence of threats such as domestic dog attack and vehicle-strike.

The resulting dataset of koala records surrounding the study area was then partitioned to enable consideration of any material changes to knowledge *post* 2001; the timeframes 2003 - 2008, 2009 – 2014 and 2015 – 2019/20 approximating the time intervals for the three most recent 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 International Union for the Conservation of Nature criteria that place weight on the concept of population change over a period of three (taxon-specific) generations (WCUSSC, 1994). Of particular interest was any evidence of generational persistence, defined as the presence within a given grid cell of one or more koala records for each of the three contributing generations. To investigate this aspect, we used the same 2.0 km x 2.0 km fixed grid overlay as that employed for the earlier analyses across the PSLGA by Biolink (2016).

c) Field Survey

Field sites were located at 500 m sampling intervals across the study site, increasing to 350 m within the LoDA. Sites could be moved up to 50 m or 35 m respectively if they did not immediately intersect

with an area of native vegetation. Universal Transverse Mercator (UTM) coordinates were determined for each corresponding point and uploaded into hand-held Global Positioning System (GPS) units to enable location in the field. Koala activity at each point was assessed using the Spot Assessment Technique (SAT) protocols of Phillips & Callaghan (2011), applied in both Full SAT (*i.e*. 30-tree samples) and Rapid-SAT formats (see below).

Full SAT assessments were conducted at each of the 350 m sampling intersections that were located within the LoDA. Elsewhere, Rapid-SAT protocols were initially applied at each of the 500 m sampling intervals; if the Rapid-SAT assessment was positive (*i.e*. koala scat detected) a Full SAT was undertaken around the tree at which the koala scat had been detected; if the Rapid-SAT assessment was negative, a standardised vegetation assessment[3] was implemented to further inform decisions about PCT/koala habitat classification. If insufficient PKFTs as required for purposes of the Rapid-SAT approach (see below) were not present within 50 m of the sampling point, and in addition to the standardised vegetation assessment, a 15 person minute search for koala scats around the bases of proximal trees > 300 mm DBH was implemented so as to be in accord with Rapid-SAT protocols.

In contrast to a Full SAT approach, Rapid-SAT focuses only on the presence/absence of koala faecal pellets within a prescribed search area of 1 m around the bases of PKFTs ≥ 300 mm DBH. This approach offers a resource-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 DBH (Phillips and Wallis 2016). This 50% probability of 'success' thus becomes an important metric for assessment purposes because it also allows utilisation of the probability of 'failure' (also 50%) in order to determine how many PKFTs without faecal pellets need to be recorded at a given sampling point in order to prescribe with a measure of statistical confidence that koalas are not using the habitat that is otherwise available in the immediate area.

Informed by the probability model of McArdle (1990), and with the guidance from further work by Kéry (2002) and Murn & Holloway (2016), **Figure 2** illustrates the probability function curve based on a constant 50% failure metric. This graph and associated function confirm that the absence of koala faecal pellets from within the prescribed 1 m radial search area around the bases of a minimum of **five** and a maximum of **seven** PKFTs > 300 mm DBH is sufficient to be 95% – 99% confident that koalas are not using habitat in the immediate area. For Rapid-SAT purposes, survey work at a given sampling point thus ceases when one or more koala faecal pellets have been detected because the

[3] All species in tallest stratum are listed, with relative abundance / dominance estimated by an 8-point intersect sample using cardinal and intermediate compass points.

objective of the assessment – koala presence - has been achieved. Conversely, if no pellets are detected, sampling ceases once a minimum of five to maximum of seven nearest neighbour PKFTs with DBHs > 300 mm have been assessed, these numbers affording a high level of statistical confidence (*e.g*. 95% or 99% respectively) that koalas are not using habitat in the immediate vicinity of the site being assessed.

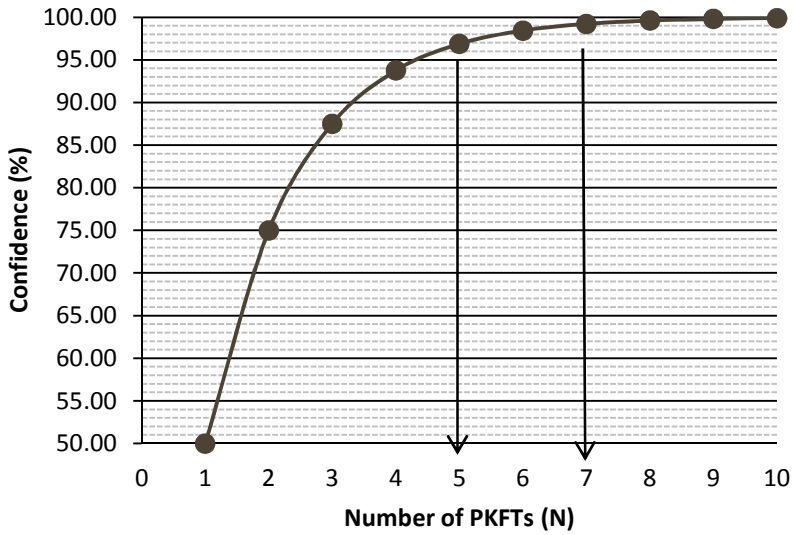

Figure 2. Statistical confidence in the probability of non-occurrence of koalas at an individual **Rapid-SAT** site based on the numbers of sampled PKFTs > 300 mm DBH beneath which no koala faecal pellets have been detected. Expansion is based on knowledge that in areas being utilised by koalas, there is an approximately 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. Arrows indicate associated numbers of PKFTs that are required to be sampled to inform conclusions of absence with 95 – 99% confidence.

Where significant koala activity levels were recorded, infill sites centrally located amongst the surrounding 500 m sites were created to assist modelling output where the activity gradient transitioned from High or Medium to Low. The approach to assessment of infill sites was the same as that specified for all 500 m sites outside the LoDA, *i.e*. Rapid-SAT – Full SAT or vegetation and faecal pellet search. The centre tree of all field sites was double flagged to enable accurate relocation for auditing and/or verification purposes.

Spotlighting

A series of spotlighting transects were created to sample both the LoDA and elsewhere across the study site. Spotlighting transects were determined upon arrival at the site and prior to the commencement of the SAT survey so not be unduly bias by any knowledge regarding the distribution of koala activity across the site.

d) Spatial Modelling and Data Analysis

Koala activity data from all sampled field sites were interpolated using regularised, thin-plate splining techniques using the default analytical parameters of the Spatial Analyst extension in ArcGIS 10.5. Splining is a mathematical process operating over a one-dimensional surface that enables information between series of proximally located data points to be exchanged and interpolated, and so illustrate progressive gradients of change. Output from the splining process was then utilised to produce activity contours delineating areas occupied by resident koala populations by identifying contours conforming to that of the 10% and 13% significant activity thresholds of Phillips & Callaghan (2011) as detailed in **Table 1**.

Table 1. Categorisations of koala activity based on use of mean activity level ± 99% confidence intervals. Activity levels in the medium (normal) and high use range for East Coast (low) activity categories indicates occupancy levels by resident koala populations (Source: modified from Table 2 in Phillips and Callaghan 2011).

Activity category	Low use	Medium (normal) use	High use
East Coast (low)[1]	< 9.97%	≥ 9.97% but ≤ 12.59%	> 12.59%

The preceding approach produces a meta-population model (or koala activity contour map) that delineates important areas of habitat that are currently supporting resident koala populations. Used widely in NSW, Victoria, Queensland, and most recently South Australia, these modelled areas of significant koala activity invariably encapsulate most contemporary koala records, but significantly capture 100% of observed breeding females (Biolink 2007). To guide modelling output, null (0 activity) sites were located around the quarry pit.

e) Post-hoc analyses

Observations during the field survey suggested differences in plant community vitality / vigour between higher and lower elevations of the study site. Using the DBH of *Eucalyptus* spp. as our dependent variable, we took the mid-point value of our lowest and highest elevation measurements from the associated SAT sites and used this to partition data into higher and lower elevation sets, respectively. The resulting data sets were tested for normality prior to comparative analysis.

To enable comparison with NSW Koala Habitat Suitability Model, we also partitioned the study site into 25 ha grid cells, the size of which reflected our 500 m x 500 m survey grid. We then used point-based data from SAT / Rapid-SAT assessments to inform considerations of habitat type / quality in accord with the hierarchical classification procedures detailed in Appendix 1.

3. Results

Analyses of historical koala records

The numbers of koala records available for the PSLGA from the BioNet database increased substantively from the nearly 8,000 for the years 1920 – 2015 that were considered by Biolink (2016), to now 10,405 for the period 1800 – 2020. A further 315 records were provided by Port Stephens Koalas and members of the Brandy Hill and Seaham Action Group, 151 of which could be located with sufficient accuracy (+/- 100 m) to be used in analyses. The majority (77%) of these useable records occurred within a 5 km radius of the Brandy Hill quarry and so became integral in terms of informing our considerations of general distribution, but most importantly generational persistence.

Eight of the 24 x 2 km x 2 km grid cells falling within a 10 km radius of the quarry site[4] returned evidence of generational persistence, four of which directly adjoined the study site to the south and west, with other cells indicated in the localities of Duns Creek and Glen Oak to the north. **Figure 3** illustrates the current extent of generational persistence, within which approximately 1500 ha of habitat is contained (~ 704 ha adjoining the study site, ~ 814 ha in the four cells to the north).

Field survey

Field survey was completed over a 5-day period 5 – 9th October 2020, during which time 28 field sites (26 primary, 2 infill) were assessed. Evidence of habitat utilisation by koalas in the form of diagnostic faecal pellets was recorded in 9/26 of the primary survey sites, thus inferring a naïve occupancy estimate for the study site of 34.62% ± 9.33% (SE) of the otherwise available habitat. Activity levels in active sites ranged from 3.33% – 33.33%, with six of the nine positive sites returning significant activity levels (*i.e*. High or Medium (normal) Use) as previously detailed in Table 1. **Figure 4** illustrates the distribution of survey effort across the study site while Appendix 2 provides a summary of the survey data. Original field data sheets for each field site are provided in a separate file (BHQ_Data_Sheets.pdf) attached to this report.

[4] These are the same grid cells utilized in the Biolink (2016) analyses.

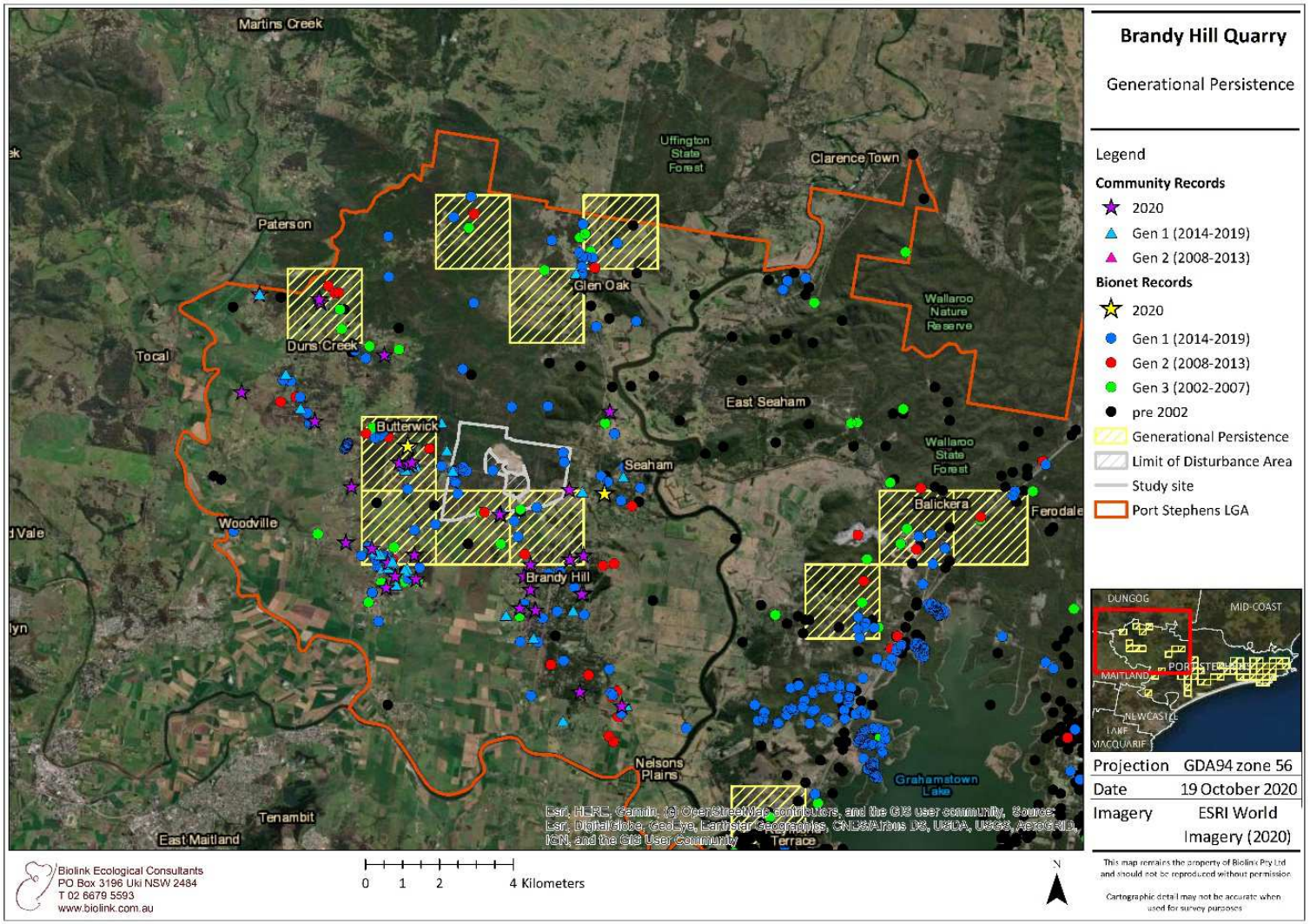

Figure 3. Areas of koala Generational Persistence (Yellow hatched grid cells).

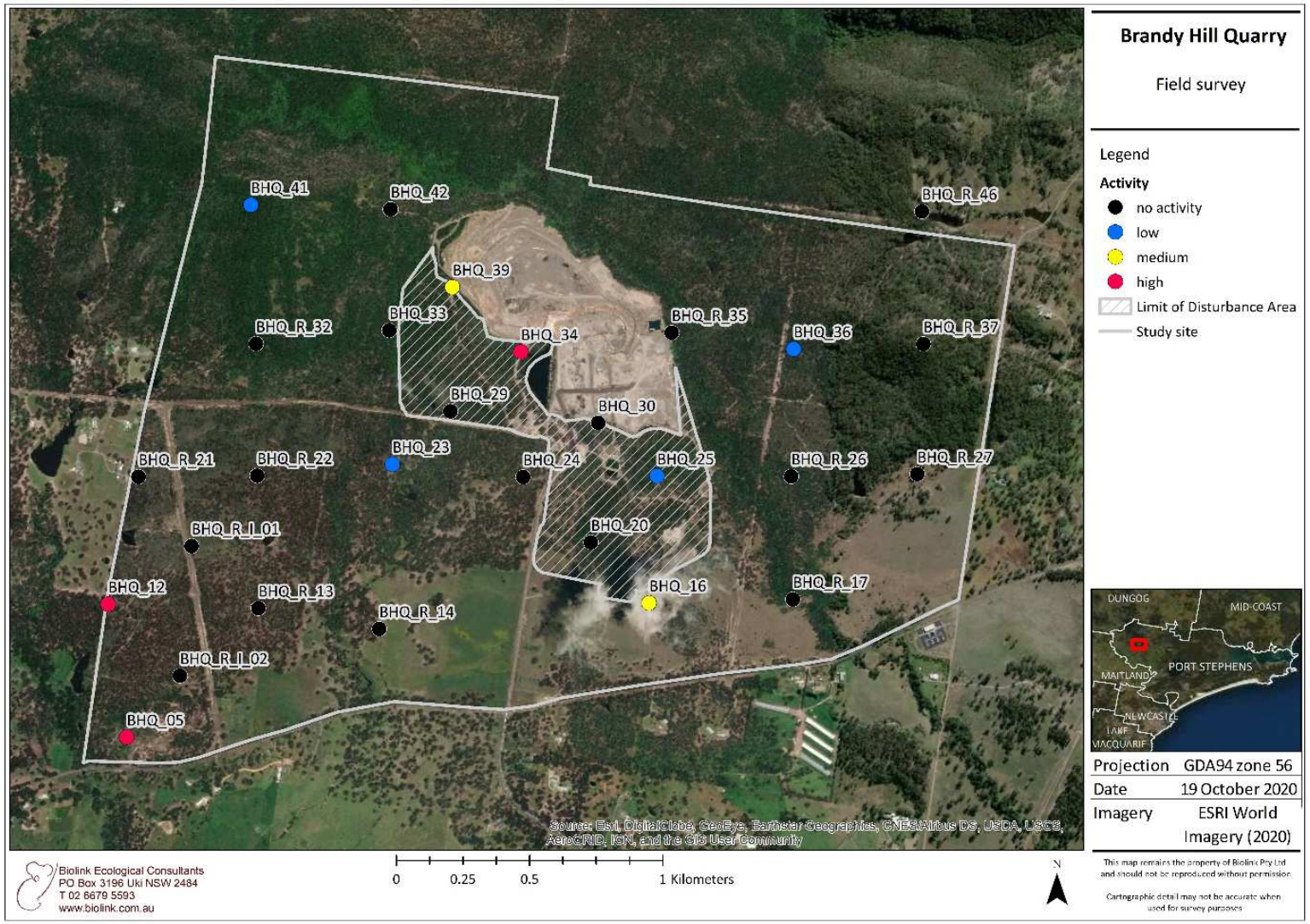

Figure 4. Distribution of survey effort.

Spotlighting

Spotlighting was undertaken within the LoDA and elsewhere within the study site over 3 non-consecutive nights 5/10, 7/10 and 9/10. The total length of surveyed transect (8 segments A – H) was 7.85 km to conservatively census an estimated area of 28.9 ha. Approximately 30 person hours of spotlighting effort were involved. No koalas were observed. While it remains speculative, it follows from this that, even if the spotlighting survey was conducted for a further night and a koala was observed, the density estimate would be 0.035 koalas ha^{-1} at best, 0.009 koalas ha^{-1} if the average[5] was considered. Table 2 provides a breakdown of the survey results, which include 3 instances of male koala bellowing at variable distances from the observer. **Figure 5** illustrates the locations of the 8 spotlighting legs, including the locations and approximate directions to which male koalas were heard calling. One of these males was subsequently located outside of the transect area by way of a focussed additional search effort in the LoDA on the same night that it was heard calling (Figure 5 refers).

Table 2. Results for spotlighting transects (Figure 5 refers), which also shows the approximate locations at which male koalas were heard calling (*n* = number of times each transect was surveyed; H = heard; O = Observed).

Leg	~ Length (m)	Width (m)	ha	*n*	Result(s)
A	2000	40	8.0	3	Koala (H x 2), Sugar Glider (H), B-t Possum (O), Owlet Nightjar (H), Cat (O).
B	550	40	2.2	2	B-t Possum (O).
C	1350	40	5.4	3	B-t Possum (O); W-t Nightjar (O).
D	650	20	1.3	3	Nil
E	350	40	1.4	2	Nil
F	1200	30	3.6	3	B-t Possum (O), W-t Nightjar (H), Koala (H)
G	650	40	2.6	1	Nil
H	1100	40	4.4	1	B-t Possum (O).
	7,850		**28.9**		

[5] The average, rather than the maximum number sighted, better reflects true density because it accommodates consideration of transient individuals such as young and highly mobile, dispersing males.

Spatial modelling

Interpolation of koala activity data across the study site identified the presence of three significant koala activity cells. The first of these is an area of approximately 50 ha located in the extreme southwestern corner of the study site extending onto adjoining lands to the west and southwest, the second being more centrally located to the east and thereafter extending southwards onto adjoining lands. The third cell is discrete and aligned along the southern edge of the quarry pit. **Figure 6** illustrates the distribution of koala activity contours, and hence the locations of resident population cells across the study site.

Post-hoc analyses

Based on an informed coding of the 25 ha grid cell overlay based on the criteria in Appendix 1, approximately half (55%) of the available koala habitat across the study site was classified as Secondary (Class B) Koala Habitat, the balance comprising Secondary (Class C / Marginal) Koala Habitat. As detailed in Appendix 1, Secondary habitat types lack primary food trees and are capable of naturally sustaining koalas only at low density. **Figure 7** illustrates the distribution of the two habitat categories across the study site.

Field data further revealed a significantly higher habitat quality at lower elevations, trees in these areas (including PKFTs) achieving greater girth on average (300 mm DBH *vs* 239 mm DBH, Kolmogorov – Smirnoff D = 0.10378; Mann-Whitney 1-tailed test: z = 2.27466, P = 0.0116). In addition to the clear differences in habitat quality, this ancillary information further highlights the importance of re-establishing connectivity along the southern periphery of the study area relative to other locations within it, more so given that the lower lying elevations also support the greater proportion of significant koala activity that occurs on the study site.

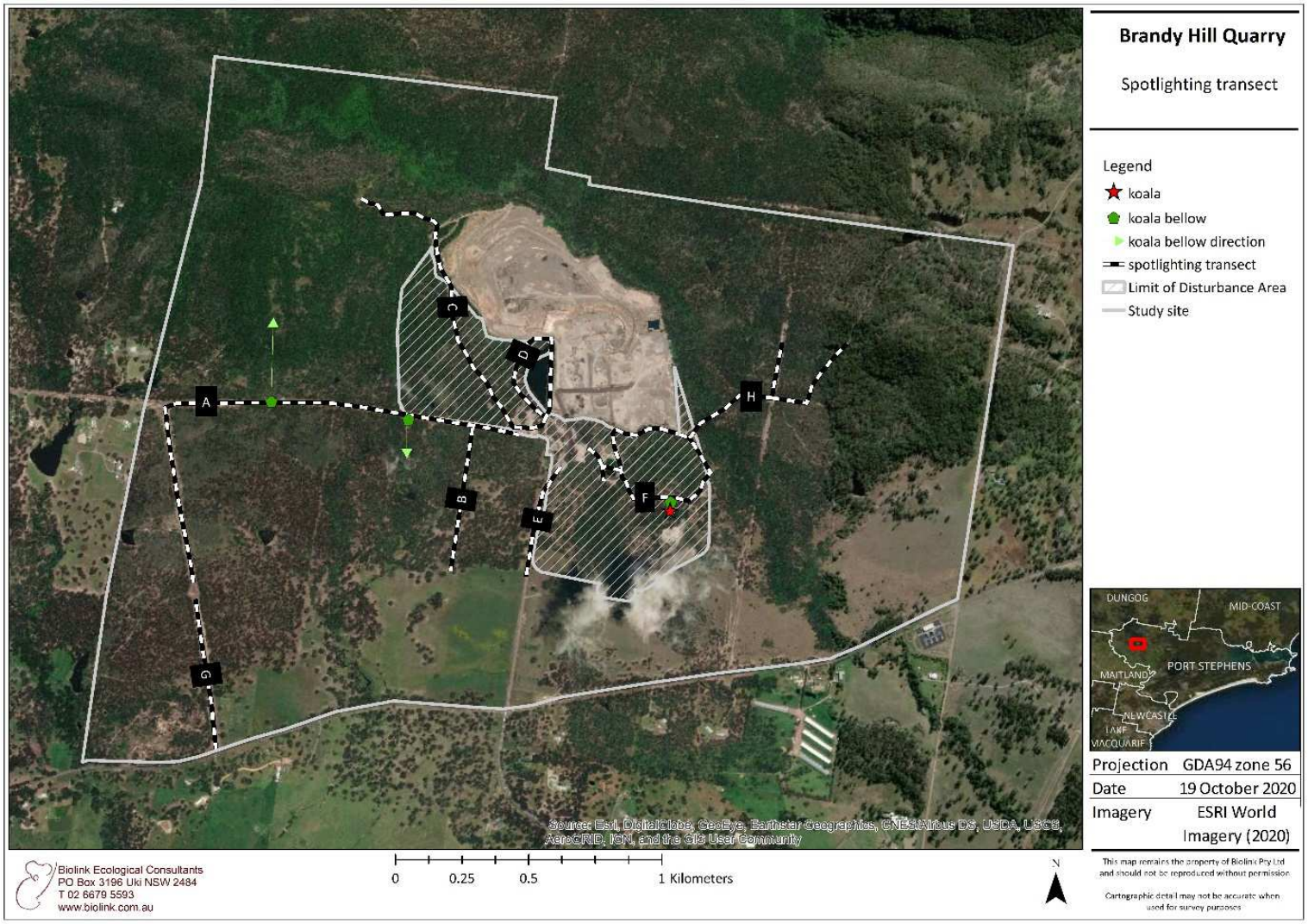

Figure 5. Locations of spotlighting transects. The location of the young male koala detected off transect is indicated by a red star.

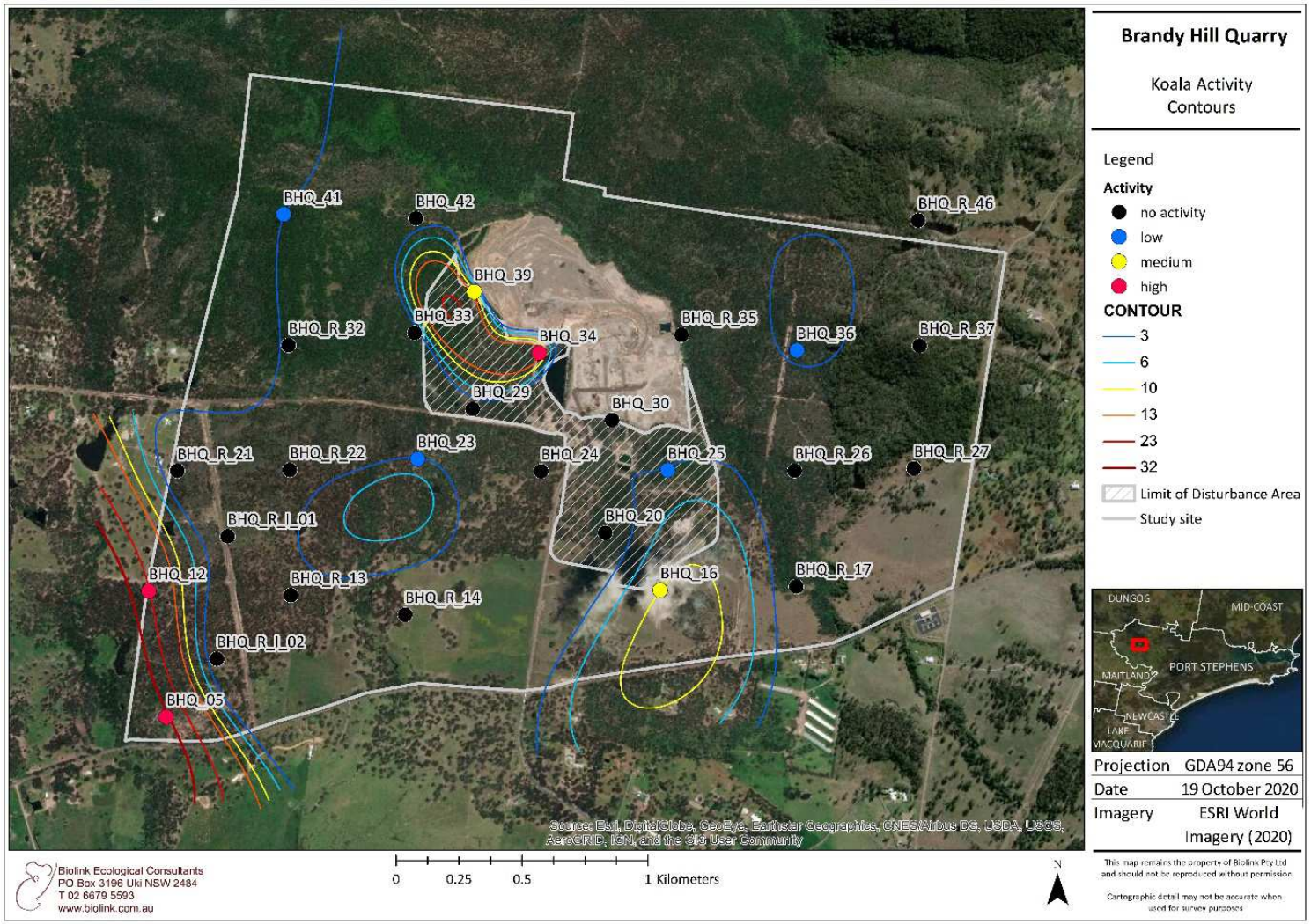

Figure 6. Koala activity contours. Note that the boundaries of significant koala activity are indicated by the yellow and red lines.

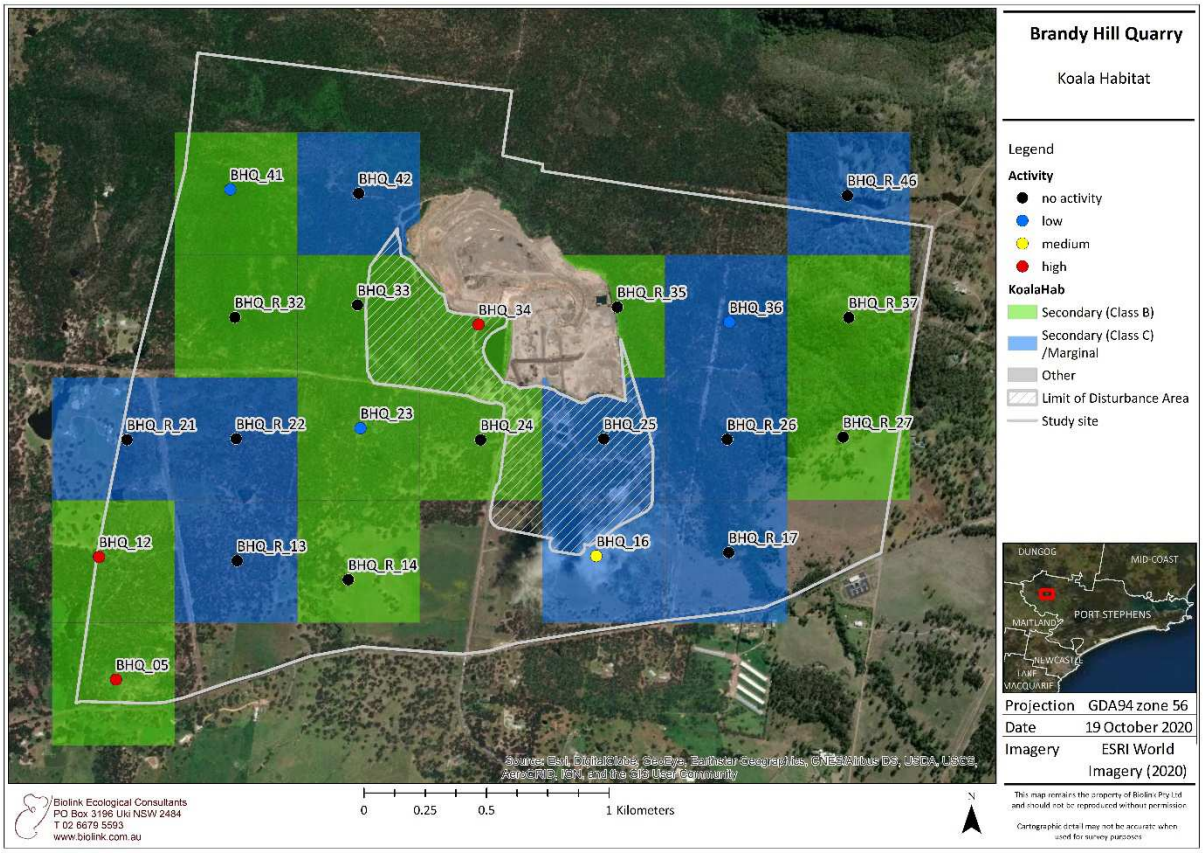

Figure 7. Distribution of Secondary (Class B) and Secondary Class C/ Marginal koala habitat across the study area

A selection of site images illustrating variation in site quality and other outcomes arising from the field survey are provided in Appendix 4.

4. Discussion

This report describes the nature of koala habitat and the associated distribution of koala activity across lands comprising the Brandy Hill quarry site. Consistent with the earlier trend identified by Biolink (2016, 2018b) an updated records analysis, augmented by community records not otherwise available for analyses, confirms an ongoing recovery trend in the area between Seaham, Woodville, Duns Creek and Glen Oak, which also includes at least part of the quarry lands. The extent of this recovery is now evident in the form of at least 3,200 ha of identified generational persistence which collectively contains ~ 1,500 of koala habitat. This estimate exceeds the minimum proposed by Biolink (2018b) as necessary to sustain a naturally occurring, low-density koala population hub. The scale of this extent is also of relevance, implying as it currently does the presence of locally important population hubs we would collectively estimate to be supporting in the order of at least

75 – 150 individuals (1,500 ha of koala habitat at (say) 0.05[6] - 0.1 koalas ha^{-1}). Further, we consider that the current absence of generational persistence in the area between the two clusters identified in Figure 3 to likely reflect low observer density and absence of survey effort; hence both the full extent of the hub and the estimated population size within is likely to be larger. Evidence in support of this assertion comes from biobanking assessments undertaken in 2016 on lands immediately adjoining the quarry site to the north, which reported a naïve occupancy rate by koalas at that time of ~ 20% of the available habitat [redacted] Based entirely on records analyses, Biolink (2016) estimated the likely size of the Port Stephens koala population as ~ 1,200 individuals in 2015. Given that populations east of the Pacific Highway are in decline, it is feasible that such loss is increasingly being offset by gains west of the Pacific Highway, hence there is little merit in substantively changing the 2015 population estimate at this point in time. Consistent with the recovery trend west of the Highway, community records reveal increasing trends in threatening processes such domestic dog attack and, to a lesser extent vehicle-strike.

Survey data implies widespread movement and use of the site by koalas, albeit Low Use as defined by Phillips and Callaghan (2011), the implication being that movements across the greater proportion of the study site by koalas at this point in time are largely random and comprised mostly of young dispersing males. In contrast, the more sedentary breeding aggregations will be restricted to areas within the Medium (normal) and High use areas as identified by Figure 6 of this study, both of which are located in the south western and more southern areas of the site beyond the LoDA. Beyond this area and at this point in time, spotlighting data implies that koala density across the site will arguably be less than 0.03 koalas $ha^{-1,}$ which in turn implies an estimated population size of less than 18 koalas within the 640 ha of the study site, and at best, no more than 1 - 2 within the LoDA. To put this density estimate into context, Biolink (2017) reported a density estimate of 0.34 koalas ha^{-1} in the Anna Bay koala population hub to the east of the Pacific Highway within the PSLGA.

With regards to the activity cell we have identified near the quarry face within the LoDA, we consider this to be more likely associated with Brush-tailed Possum activity, than we do koalas. Our reasons for this qualification are as follows:

- Splining and contouring reveals only a small area of significant activity, the extent of which is less than that required to support a single koala in this habitat type, nor did we detect any indication of connectivity with the larger population cell located to the southwest; such a

[6] This density derived from two independent studies undertaken on equivalent habitat types at Kings Hill and Grahamstown Dam in the PSLGA.

localised pattern of activity is atypical of that normally associated with the presence of a resident koala population cells in this type of habitat.

- As evidenced by the low activity levels that were recorded (13% and 10%) the observed scats were both uncommon and in low numbers (also atypical of a resident koala population cell), as well as being old and not primarily located at the base of sampled PKFTs.
- When relatively fresh, koala scats and brush-tailed possum scats can be readily distinguished from each other (Koala: elliptical shape, non-odorous +/- longitudinal ridges, Brush-tailed Possum: cylindrical, odorous, no longitudinal ridges +/- concave) but with older / partial scats some overlap can occur.
- Spotlighting survey through this area over three non-consecutive nights failed to observe a koala in this area but did record Brush-tailed Possums on each occasion.

Regardless of the preceding qualifications, we have presumed for the purpose of this report that the activity is koala-related and have structured recommendations accordingly.

Expansion of the LoDA has the potential to negatively impact upon east-west movement across lower reaches of the study site. As established by this study, field data identifies the lower reaches of the study site as supporting the higher quality habitat areas. The predominance of Lantana thickets in north-western areas of the study site was noted during the field survey (and is also evident in aerial imagery) may well be a contributing factor to this outcome, working to both impede access and colonisation by koalas (despite the presence of PKFTs) and also negatively influencing plant vitality, and general ecosystem health through water sequestration (Mandal and Prasad Joshi 2015).

The matter of east-west connectivity was also identified in the report by Witt and Clulow (2020), along with broader concerns about the potential impacts on koalas arising from an expansion of the quarry footprint generally. It is apparent that these concerns were partly based on the results from spotlighting work undertaken on adjoining properties which had detected koalas. Thus, it was not entirely unreasonable to assume that koalas would be equally detectable within the quarry property. However, the concerns of Witt and Clulow (2020) were also informed by the NSW Government's Koala Habitat Suitability Model (KHSM), which indicated the presence of high quality koala habitat in the area within and surrounding the quarry site, a notion that was at odds with available historical and more recently updated koala habitat models for the PSLGA (Lunney *et al*. 1998; Biolink 2017). While we consider that the desktop review by Witt and Clulow (2020) should have perhaps considered these other habitat models and associated information that was readily available (at

least for the purpose of a comparative review), we can also appreciate the focus on a supposedly more refined approach taken by the KHSM and associated attributes.

The KHSM predicts habitat suitability for koalas using values between 0 - 1, the higher the value the more likely the habitat is perceived to be suitable for koalas. The KHSM was derived using a predictive Maxent model and expert elicitation. Unfortunately, the model was validated using only a small number (*n* = 65) of field sites and is further limited by the accuracy of underlying vegetation mapping, while also being reliant upon historical records, a poor understanding of tree use by koalas and a gender-biased field survey method (acoustic sampling), all of which increase the potential to skew survey results. The KHSM predicted koala habitat suitability within the study area to be high (0.71) relative to other nearby areas, and this in turn underpinned the concerns expressed in the desktop review by Witt and Clulow (2020). Their concerns were also informed by well-intentioned community advocacy, all of which, by inference, implied the presence of a resident koala population inhabiting the entire study site. As our survey results have demonstrated, this is not the case, illustrating that reliance upon the mapping layers and indexes of the KHSM when used without regard for local site-specific data/knowledge can work to misrepresent the importance of many areas at both ends of the koala habitat quality spectrum.

As evidenced by the results of this study, site-based SAT data offers a superior approach to determining habitat suitability for koalas. The Grid-SAT approach offers several advantages over other techniques because:

- Its genesis and development were initially based on a substantive data set (14,313 trees from 405 spatially independent field sites) relating to habitat / tree use by koalas.
- It offers unbiased point-based koala activity data that is focused as a scale relevant to the habitat category and species in question.
- The point-based data is suitable for modelling while gathering other useful data relating to habitat use by koalas and forest / PCT structure.

In addition to the preceding dot points and as evidenced by the numerous studies completed throughout the koala's range in eastern Australia that have been informed by the grid-based approach outlined herein (Appendix 3 refers), the SAT approach embodies best practice by and amongst other things being able to unambiguously distinguish between areas being utilised by resident populations *vs* areas being used by koalas for other purposes, and for identifying and ranking (in terms of koala carrying capacity) areas of preferred koala habitat, while also enabling point-based validation of constituent PCTs. While we are aware of a positive relationship between

koala activity (as measured by SAT metrics) and koala density *per se*, this material is yet to be published and has not been included in this work. Instead we have relied upon spotlighting because of its proven success in recording koalas in naturally occurring low-density populations (Wilmott *et al.* 2018). Indeed, replicated spotlighting and/or daylight transect searches have been our primary direct-count technique for projects such as this for many years (Appendix 3 refers). Locally, the use of such direct count techniques in identical habitat types to that found at Brandy Hill but otherwise located along the western edge of Grahamstown Dam (Biolink 2020) and in the Kings Hill area (Biolink 2018a) have all returned low density estimates of ~ 0.05 koalas ha^{-1} for less survey effort than what we have applied in this instance. Hence, our spotlighting data and independently derived occupancy / habitat utilisation data afforded by the SAT are in strong agreement that the greater proportion of the study site is currently the focus of Low / transient use by koalas. This does not mean that the potential for negative impact can be discounted, rather that at this point in time it can be avoided and effectively managed without the potential for a significant impact on the area's koala population. Moreover, our survey data provides the basis for a more proactive management response to be developed that potentially has longer-term benefits for koalas in the area, to which end the following recommendations are proposed for consideration in the event that expansion of the quarry footprint is approved by the Commonwealth.

5. Recommendations

1. The quarry site offers a relatively large area of potential koala habitat that would benefit from on-site management and rehabilitation. We thus propose that some consideration be given to use of the balance of the site for biobanking / offsetting purposes, either in its entirety or in parcel with other offsetting obligations.

2. Regardless of 1 above, the balance of the unvegetated lands south of the proposed amenity bund should be dedicated to habitat restoration works in order to ensure the longer-term maintenance of east-west connectivity across the study area which will otherwise be impacted and become non-functional once LoDA is fully cleared. To this end we propose the need for a two-stage habitat restoration plan to be prepared and submitted for approval prior to development consent being granted, Stage 1 of which must be approved and in effect prior to the commencement of latter stages of vegetation clearing within the LoDA.

3. In order to maintain east west connectivity, a 100 m vegetated buffer is to be retained at the southern edge of the LoDA north of the amenity bund until such a time as sufficient vegetation cover is present within the Stage 1 restoration works to enable the safe passage of koalas. A schematic

illustration of this outcome is provided in **Figure 8**. For context, Figure 8 also includes the locations of various least-cost koala dispersal pathways that were independently modelled for the Brandy Hill area as part of a broader project (Biolink 2018b) furthering an understanding of koala connectivity requirements across the entire PSLGA.

4. While we are in some doubt as to the presence of a resident koala population cell within the LoDA, a precautionary approach is warranted given the presumption that at least one resident animal may be present. All care should be taken to ensure that this animal can safely egress from the area to be cleared. This can be achieved by commencing clearing activity in the south at the current quarry habitat interface and progressing to the northwest and southeast under supervision of an on-site ecologist. In the event that a koala is observed, machinery should not approach within a minimum distance of 25 m, forest cover should be maintained ahead of the general direction in which the koala is expected to disperse across, and the animal must be allowed to egress of its own volition.

In the event that a koala is sighted within the LoDA and despite the provisions of the preceding paragraph, it remains in the same tree for more than 3 consecutive nights, it should be captured and placed into care for the duration of the clearing event, where after it must be released at the nearest vegetated area to where it was captured.

5. A habitat restoration plan, nominally developed in conjunction with 3 above, should also prioritise weed control/eradication in the western areas of the site, the intent of which is to increase water availability to native species, improve access for koalas and so facilitate occupancy by resident population cells.

6. Long-term monitoring of habitat use by koalas, as well as the response of the landscape to habitat restoration measures within and across the study site should be required annually for a minimum of 5 years as a condition of approval. We consider the data collected by the 500 m Grid-SAT approach to offer useful baselined data against which future changes in habitat use can be measured.

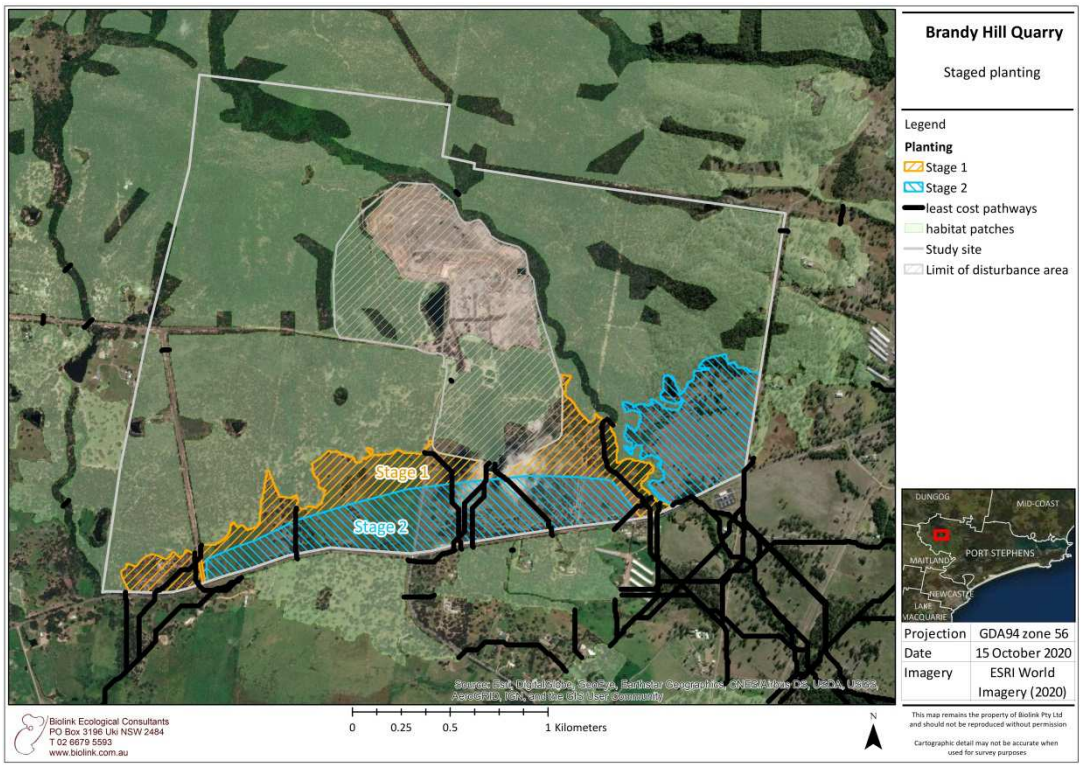

Figure 8. A conceptual 2-stage habitat restoration plan intended to secure east-west connectivity across the Brandy Hill study site. The locations of least-cost dispersal pathways for koalas previously modelled by Biolink (2018b) for the PSLGA are also illustrated as solid black lines.

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Appendix 1

Preferred Koala Food Tree Types and their application to the task of koala habitat classification.

The carrying capacity of koala habitat is a reflection of habitat quality which can be measured firstly in terms of disturbance history, and secondly in terms of the type and relative abundance of Preferred Koala Food Tree (PKFT) species that are present. With regard to PKFT 'type', *Primary* PKFTs display use by koalas that is significantly higher than other congeners, with a measure of utilisation by koalas being demonstrably independent of size class (Phillips *et al*. 2000), while *Secondary* PKFTS similarly display a level of use that is significantly higher than other congeners (excluding Primary PKFTs), but which and in contrast to primary PKFTs, exhibit a utilisation model by koalas that is demonstrably size-class dependent (Phillips and Callaghan 2000), with preferential utilisation commencing at DBHs > 300 mm.

Table A1.1. A five-tiered, hierarchical approach typically applied to the task of classifying koala habitat in terms of potential carrying capacity.

PKH type	Classification criteria	Carrying capacity
Primary	Forest and/or woodland communities occurring on soils of medium to high nutrient value whereupon primary PKFTs are dominant[7] or co-dominant[8] components of the tallest stratum species	> 0.5 koalas ha^{-1}
Secondary (Class A)	Forest and/or woodland communities occurring on soils of medium to high nutrient value whereupon primary PKFTs are sub-dominant[9] components of the tallest stratum species	> 0.25 and < 0.5 koalas ha^{-1}
Secondary (Class B)	Forest and/or woodland communities occurring on soils of low to medium nutrient value whereupon primary PKFTs are absent, the tallest stratum instead dominated or co-dominated only by secondary PKFTs > 300 mm dbh.	> 0.1 and < 0.25 koalas ha^{-1}
Secondary (Class C) / marginal	Forest and/or woodland communities occurring on soils of low to medium nutrient value whereupon primary PKFTs are absent and secondary PKFTs > 300 mm dbh are sub-dominant components of the tallest stratum species	< 0.1 koalas ha^{-1}
Other	Forest and/or woodland communities that do not contain PKFTs.	NA
Unknown	Vegetation communities not currently mapped and/or described.	NA

[7] Wherein PKFTs comprise on average ≥ 50% of the tallest stratum species

[8] Wherein PKFTs comprise on average ≥ 35% but < 50% of the tallest stratum species.

[9] Wherein PKFTs comprise on average < 35% of the tallest stratum species.

Appendix 2

SAT survey results (FPS = Faecal Pellet Search; Use_Code = Activity category as defined in Table 2 of Phillips & Callaghan (2011); Hab_Code = Habitat Classification as detailed in Appendix 1; Site Numbers in red are those located within the LoDA).

Site Number.	Rapid-SAT	Result	Full SAT	FPS	Activity (%)	Use_Code	Hab_code
Primary Field Sites							
BHQ_5	yes	+ve	yes	na	33.33	High	2(b)
BHQ_12	yes	+ve	yes	na	23.33	High	2(b)
BHQ_13	No PKFTs	-	no	yes	0.00	Low	2(c)
BHQ_R_14	yes	-ve	no	yes	0.00	Low	2(b)
BHQ_16	yes	+ve	yes	na	10.00	Medium	2(c)
BHQ_17	No PKFTs	-	no	yes	0.00	Low	2(c)
BHQ_20	-	-	yes	na	0.00	Low	2(c)
BHQ_21	No PKFTs	-	no	yes	0.00	Low	2(c)
BHQ_22	yes	-ve	no	yes	0.00	Low	2(c)
BHQ_23	yes	+ve	yes	na	3.33	Low	2(b)
BHQ_24	-	-	yes	na	0.00	Low	2(c)
BHQ_25	-	-	yes	na	3.33	Low	2(c)
BHQ_26	No PKFTs	-	no	yes	0.00	Low	2(c)
BHQ_27	Yes	-ve	no	na	0.00	Low	2(b)
BHQ_29	-	-	yes	na	0.00	Low	2(c)
BHQ_30	-	-	yes	na	0.00	Low	2(c)
BHQ_32	Yes	-ve	no	na	0.00	Low	2(b)
BHQ_33	Yes	-ve	no	yes	0.00	Low	2(b)
BHQ_34	-	-	yes	na	13.33	High	2(b)
BHQ_35	yes	-ve	no	na	0.00	Low	2(b)
BHQ_36	yes	+ve	yes	na	3.33	Low	2(c)
BHQ_37	yes	-ve	no	na	0.00	Low	2(b)
BHQ_39	-	-	yes	-	10.00	Medium	2(c)
BHQ_41	yes	+ve	yes	na	3.33	Low	2(b)
BHQ_42	-	-	yes	-	0.00	Low	2(c)
BHQ_46	yes	-ve	no	na	0.00	Low	2(c)

Infill Sites							
BHQ_I_01	No PKFTs	-	no	yes	0.00	Low	2(c)
BHQ_R_I_02	No PKFTs	-	no	yes	0.00	Low	2(c)

Appendix 3

A selection of landscape-scaled Koala Habitat & Population Assessment Studies that have been completed using Analyses of Historical Koala Records and the application of Grid-based SAT sampling.

Queensland

2007 – *Koala Habitat and Population Assessment for Gold Coast City LGA*.

2018 – *Redlands Coast Koala Population and Habitat Assessment*.

2019 – *City-Wide Koala Monitoring: Habitat Mapping and Monitoring Program*.

2020 – *Ipswich City Council Koala Assessment*.

New South Wales

2005 – *Innes Peninsula Koala Study.*

2007 – *The utility of regularised grid-based sampling for the purposes of identifying areas being utilised by a low density koala population in the South-east Forests of NSW – a Pilot Study.*

2010 - *Tweed Coast Koala Habitat Study.*

2013 - *Port Macquarie Hastings Koala Habitat & Population Assessment.*

– *Koala management Study for part of the Gunnedah Shire Council LGA.*

2015 – *Koala Habitat & population Assessment: Richmond Valley Council LGA*.

– *Aspects of koala distribution and abundance in the Coffs Harbour LGA with a focus on the Northern Management Precinct.*

2016 – *Analysing the historical record: aspects of the distribution and abundance of koalas in the Campbelltown City Council LGA 1900 – 2012.*

2017 – *Managing Koala populations for the future: constituent populations of the Central ARKS Port Stephens sub-area*.

– *Koala Habitat & Population Assessment: Lismore LGA (part).*

2019 – *The Kiwarrak and Khappinghat ARKS – Aspects of the distribution and abundance of koalas*.

Victoria

2014 – *Strzelecki Ranges Koala Survey: Corridors and Core Habitat for Koalas Project*.

2016 – *Habitat Utilisation by Koalas in the Gippsland Region*.

South Australia

2020 – *Distribution and abundance of koalas in the Belair Conservation Reserve*.

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Appendix 4

Site Images

Figure A4_a. Site BHQ_32, a Secondary (Class B) koala habitat typified by the dominance of a Secondary PKFT, in this case Grey Gum *E. punctata*. Note the dense understorey of Lantana which functions to impede access by koalas and sequester otherwise limited nutrients such as water.

Figure A4_b. Site BHQ_5, a Koala High Use area in the southwestern corner of study site. Note predominance of red gums and doubly flagged tree designating the centre of the associated SAT site.

Figure A4_c. Site BHQ_13. Secondary (Class C/Marginal) koala habitat typified by the scarcity of PKFTs. The PCT here is monopolised by Red Ironbark *E. fibrosa*, with scattered individuals of Spotted Gum *C. maculata* and the occasional small Forest Red Gum *E. tereticornis*.

Figure A4_d. Dieback of tallest and mid-stratum vegetation downslope of BHQ_42. Elevated areas of the study site tended to exhibit greater measures of water stress than did lower elevations.

Figure A4_e. A young male koala located in a Grey Box *E. moluccana* within the LoDA on the evening of the 9th October after earlier heard bellowing during the course of the beyond spotlighting transect search, but otherwise beyond transect sampling parameters. Upon leaving the maternal home range area at ~ 18 months of age, young male koalas travel widely for 2 -3 years until reaching physical maturity at ~ 4 years of age.