Koala Monitoring in SENSW Coastal Forests: 2007-19
FINAL REPORT

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Introduction and Summary

The report provides background information, a description of methods, some indicative results and discussion regarding the NSW Saving our Species-funded program that has been monitoring a small, low-density koala population extending over approximately 25,000 ha in the coastal forests of SENSW (hereinafter termed the study area) in the period 2007-9. Some information from two other studies that have contributed monitoring data are also provided. Having now retired from what is now the NSW Department of Planning and Environment (DP&E) this is a personal report.

These koalas and their habitat have been extensively studied[1],[2],[3] and in 2017 the NSW government established the 12,000 ha Murrah Flora Reserve in part to assist their conservation,[4] extending the forest reserve system in this part of the region to 30,000 ha. This include the 12,000 ha Biamanga National Park, managed by the Biamanga Board[5] with a majority of Aboriginal owners.

The NSW Chief Scientist (2016)[6] report into the decline of koala populations in key areas in NSW emphasises the importance of developing long-term koala population monitoring programs. The ensuing NSW Koala Strategy committed to a *koala monitoring program in partnership with other agencies…(to) monitor koala populations and their habitat and measure the effect of the actions in this Strategy*. It further states that 10 to 30 sites across different koala habitats and land tenures would be selected and that at these sites, the responsible land manager would *monitor and report on:*

- *the distribution, size, demography, genetic diversity and trends of the koala population*
- *the extent and quality of habitat*
- *the distribution, intensity and impact of threats to koalas*
- *the health of koalas*
- *the impact of management actions.*

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[1] DECCW 2010. Koala surveys in the coastal forests of the Bermagui–Mumbulla area:
2007–09 – An interim report, Department of Environment, Climate Change and Water NSW, Sydney, www.environment.nsw.gov.au/resources/threatenedspecies/10116koalabermmum.pdf

[2] Office of Environment and Heritage 2016. *2012–14 Koala survey report in coastal forests of south-eastern NSW – Bermagui/Mumbulla area*. Corridors and Core Habitat for Koalas Project, Office of Environment and Heritage, Sydney.
http://www.environment.nsw.gov.au/publications/nativeanimals/koala-survey-bermagui-mumbulla-160233.htm

[3] Eleanor Stalenberg, Ian R. Wallis, Ross B. Cunningham, Chris Allen, William J. Foley. *Nutritional Correlates of Koala Persistence in a Low-Density Population. Plos 1*
www.aph.gov.au/DocumentStore.ashx?id=b0014f33-c389-4128-aeec-9c0c798ecc2a

[4] Office of Environment and Heritage 2017. *Murrah Flora Reserves Draft Final Working Plan Mumbulla, Tanja, Murrah and Bermagui State Forests; Reserve numbers 187, 188, 189 and 190; NSW South Coast Forest Protection Area.*
https://www.environment.nsw.gov.au/research-and-publications/publications-search/murrah-flora-reserves-draft-working-plan

[5] Office of Environment and Heritage 2014. *Yuin Bangguri (Mountain) Parks Plan of Management Incorporating Gulaga National Park and Biamanga National Park.*
https://www.environment.nsw.gov.au/research-and-publications/publications-search/yuin-bangguri-mountain-parks-plan-of-management

[6] NSW Chief Scientist (2016). *Report of the Independent Review into the Decline of Koala Populations in Key Areas of NSW.* NSW Chief Scientist & Engineer December 2016. www.chiefscientist.nsw.gov.au/reports

This report provides a contribution to this monitoring commitment.

Analysis by Gruber and Aalmack (2016) [7] of grid-site data from koala surveys undertaken in 2007-9[8] and 2012-14[9] in the study area using the Regularised Grid-based Spot Assessment Technique (RGb-SAT)[10],[11] method indicated that if approximately 500 grid-sites were reassessed per koala generation there would be 90-95% confidence a 30% change in occupancy rates would be detected.

This analysis gave us the confidence to proceed with a monitoring program using the same method as the initial surveys. The RG-bSAT survey results provided the basis for the delineation of a *core area* and informed the process for selecting specific monitoring sites. The study area was also subdivided into five sub-areas and the program, commencing in 2016 and funded initially through the Commonwealth Biodiversity Fund, aimed to assess 65-100 grid-sites per annum in sequential sub-areas. By October 2019, four of the five sub-areas have been assessed and monitoring surveys are nearly completed in the fifth sub-area.

Each selected grid-site was relocated using a GPS navigator and the forest litter surrounding the closest 30 live trees over 150mm diameter at breast height was searched for koala faecal pellets within a metre of their trunks. The species, DBH and presence/absence of pellets were recorded for each tree. Ecological data was also gathered to assist with monitoring changes in other habitat quality indicators such as other fauna, canopy health, fuel hazard loads and browse species recruitment.

Community engagement has been a key component of the monitoring program. Community-based contractors including those from Local Aboriginal Land Councils, with the support of local volunteers, have undertaken almost all the fieldwork for this monitoring program.

Data was gathered electronically and uploaded into the SENSW koala database. A programming tool (*ikoala*) [12] was developed by University of Canberra biometricians and linked to the SENSW koala database, the statistical package 'R', and Google mapping software. This provided the capacity to automatically generate reports estimating koala occupancy rates in three designated survey periods using a Bayesian-based occupancy modelling approach. In its automatically generated reports *Ikoala* also maps koalas' distribution, activity level contours and tree species and size-class preferences.

Indicative *ikoala* monitoring results are provided in the Results and Appendices sections of this document. These do not indicate any discernible increase or decrease in koala occupancy rates in the study area assessed in this last period, compared with previous periods.

In the late spring of 2016 FNSW scientists undertook a passive acoustic survey where recording devices were placed at 24 of the study area's grid-sites for two weeks, 12 to the north of the Murrah River in the area delineated as Sub-area 4, and 12 to the south of the river in Sub-area 2. Koala bellows were recorded 522 times at 21 out of the 24 sites, with one site yielding 120 calls (Law et al 2019)[13].

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[7] Bernd Gruber & Aaron Adamack (2016). *Draft Report to inform the sampling effort of the Koala monitoring programme around Bega*. University of Canberra

[8] *Ibid* DECCW 2010. *Koala surveys in the coastal forests of the Bermagui–Mumbulla area*

[9] *Ibid* Office of Environment and Heritage 2016. 2012–14 *Koala survey report in coastal forests of south-eastern NSW*

[10] Phillips S and Callaghan J 2000, Tree species preferences of Koalas (Phascolarctos cinereus) in the Campbelltown area south-west of Sydney, New South Wales, Wildlife Research, vol.27, no.5, pp.509–516

[11] Phillips S and Callaghan J 2011, The Spot Assessment Technique: a tool for determining levels of localised habitat use by Koalas *Phascolarctos cinereus*, Australian Zoologist, vol.35, no.3, pp.774–780

[12] Bernd Gruber, Veronika Vyˇsn´a & Aaron T. Adamack (2014). SENSW Coastal Forests Koala Survey 2012-2013 Analysis of occurrence, activity and tree preference – Report. University of Canberra, ACT

[13] Law, B.1, Gonsalves, L., Bilney, R., Peterie, J., Pietsch, R., Roe, P.4 and Truskinger, A. (2019). *Using Passive Acoustic Recording and Automated Call Identification to Survey Koalas in the Southern Forests of New South*

Comparing the passive acoustic survey results with pellet surveys at the same sites revealed the former had site detection rates more than three times higher than that of the pellet surveys. Passive acoustic surveys have since been undertaken in the remaining sub-areas at approximately the same time as the RGb-SAT monitoring fieldwork.

Current management initiatives in the study area aiming to support the conservation of the koala population include:

1. improving the management of fire, including supporting the introduction of cultural burning;
2. continuing the research into potential rehabilitation methods for degraded logging regrowth;
3. planting of locally endemic koala browse species on adjoining private lands;
4. supporting a strong, knowledgeable and effective community voice for local koalas.

The koalas of the SENSW coastal forests are important because of their geographic location within the wider spread of koalas across eastern Australia, genetics (unique allelles), habitat use, history, and the level of stakeholder commitment to its conservation. Monitoring such a small and widely scattered koala population is challenging.

The approaches discussed in this document contribute to our knowledge of these koalas, and levels of confidence in trends indicated in data analyses will increase as more data is gathered. Technologies and data analytic capacities associated with the monitoring are developing rapidly and these may determine profound changes in how the monitoring program is undertaken; for example, the capacity to distinguish recorded bellows from individual animals, if that were possible, would significantly improve the monitoring capacity of the passive acoustic survey method.

The NSW Koala Strategy commits to the perhaps ambitious *vision to stabilise then increase koala numbers over the longer-term, ensuring genetically diverse and viable populations across the state.* In the south eastern corner of the state, koala numbers remain low and the future of the population is not secure, despite changes to reserve status of its habitat, the removal of the threat of intensive logging across the core area utilised by the population, and the implementation of management initiatives aiming to reduce the threat of fire and improve habitat. These may make the difference between recovery and regional extinction, but only time and effective monitoring will tell us this.

A genetic and disease study was undertaken by the Koala Health Hub (University of Sydney) in the study area in Period 3 that also provided information that informs the monitoring program results. Key outcomes of this study were: a) *Chlamydia pecorum* appears likely to be absent from sub areas 1, 2 and 3 (approx. 80% certainty) to the south of the Murrah River, but is present in sub areas 4 and 5, and in Kooraban NP; and, b) here was some, but limited, mitochondrial DNA diversity within sub areas 2 and 3, with absence of genotypes from nearby Southern Tablelands and Mallacoota, but similarity to a genotype from Tubbut, Victoria; suggestive of past founder effects and/or genetic drift in the sub areas 2 and 3 populations.

RG-bSAT monitoring methods

Defining the core area for monitoring

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*Wales. Zoologis*t. 2019 Royal Zoological Society of New South Wales.
https://publications.rzsnsw.org.au/doi/abs/10.7882/AZ.2019.033

Grid-sites selected for koala monitoring were based on results from koala surveys undertaken in 2007-9 (Period 1) [14] and 2012-14 (Period 2)[15]. The surveys undertaken in those two periods were based on a 500 x 500 m grid, with its intersections providing the locations for potential sites.

From Period 2 onwards the grid used followed the UTM coordinate system, hence enabling grid-sites assessed in 2012-14 to be re-assessed in Period 3 (2015-20).

The *core area* (Figure 1) was defined by extending its boundary 1500m beyond any grid-site where koala evidence was identified in the 2007-9 and 2012-14 surveys, thus capturing areas neighbouring koala activity identified in these surveys. Quite a high degree of spatial autocorrelation was observed in these surveys, meaning that neighbouring sites of previously active site had a higher probability to be occupied than a purely randomly chosen site.

Defining sub-areas

Analysis by Gruber and Aalmack (2016)[16] of grid-site data indicated that a 90-95% confidence would detect a 30% change in occupancy if approximately 500 grid-sites were reassessed per koala generation (6 years).

To achieve this the core area was subdivided into 5 sub areas (Figure 1) and a monitoring program focussing on one sub-area per annum was initiated, commencing in 2016. This aimed to assess approximately 60-100 grid-sites per year, potentially enabling the program to focus on potential survey areas outside the study area for one year in six.

Selecting grid-sites for assessment

Grid-sites were selected for assessment by: a) including all sites that were active in 2012-14; and, b) including at least three times as many inactive sites, distributing these as evenly as possible.

The even distribution was achieved by: a) selecting all sites in the sub-site of interest then; b) selecting a random site from the remaining list of inactive sites and removing the surrounding sites to make sure the sample was distributed evenly; and, c) continuing to select in this way until three times the number of active sites were selected.

The monitoring program commenced in sub-areas 2 & 3 in 2016, selected because they are located towards the centre of the study area where higher rates and activity levels were recorded both in 2007-9 and 2012-14. Sub-area 4 was assessed in 2017 and Sub-area 5 in 2018. The assessment of Sub-area 1 is commenced September 2019 and will be completed early in 2020.

Selecting the periods

Three survey periods were selected for monitoring analyses by *ikoala* and are reported on in this document: *Period 1*: 2007-9; *Period 2*: 2012-14; and *Period 3*: 2016-19. These coincide with the three main phases of fieldwork undertaken in the study area.

Methods used in the field

The Period 3 monitoring program used the same assessment method in the field as that used in Periods 1 & 2 (Regularised Grid-based Spot Assessment Technique (RG-bSAT)). At each grid-site the base of the closest 30 live trees over 150mm diameter at breast height (dbh) were searched for Koala

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[14] DECCW 2010. Koala surveys in the coastal forests of the Bermagui–Mumbulla area: 2007–09 – An interim report, Department of Environment, Climate Change and Water NSW, Sydney, www.environment.nsw.gov.au/resources/threatenedspecies/10116koalabermmum.pdf

[15] Office of Environment and Heritage 2016. 2012–14 Koala survey report in coastal forests of south-eastern NSW – Bermagui/Mumbulla area. Corridors and Core Habitat for Koalas Project, Office of Environment and Heritage, Sydney. http://www.environment.nsw.gov.au/publications/nativeanimals/koala-survey-bermagui-mumbulla-160233.htm

[16] Bernd Gruber & Aaron Adamack (2016). *Draft Report to inform the sampling effort of the Koala monitoring programme around Bega*. University of Canberra.

faecal pellets out to a metre from their trunks. The species and dbh of each of the 30 trees were recorded. The distance from the centre tree to the furthest tree in each site was recorded as the radius of the site.

The proportion of trees with Koala pellets compared with the total number of trees assessed at each site (30 per site) is termed the site's *activity level* (Phillips et al. 2000, Phillips and Callaghan 2000, Phillips 2000) (i.e. 1 tree with pellets = 3.33% activity; 2 trees with pellets = 6.67%; 3 trees with pellets = 10%, and so on). The activity level at each of the 918 sites was calculated (Figure 2).

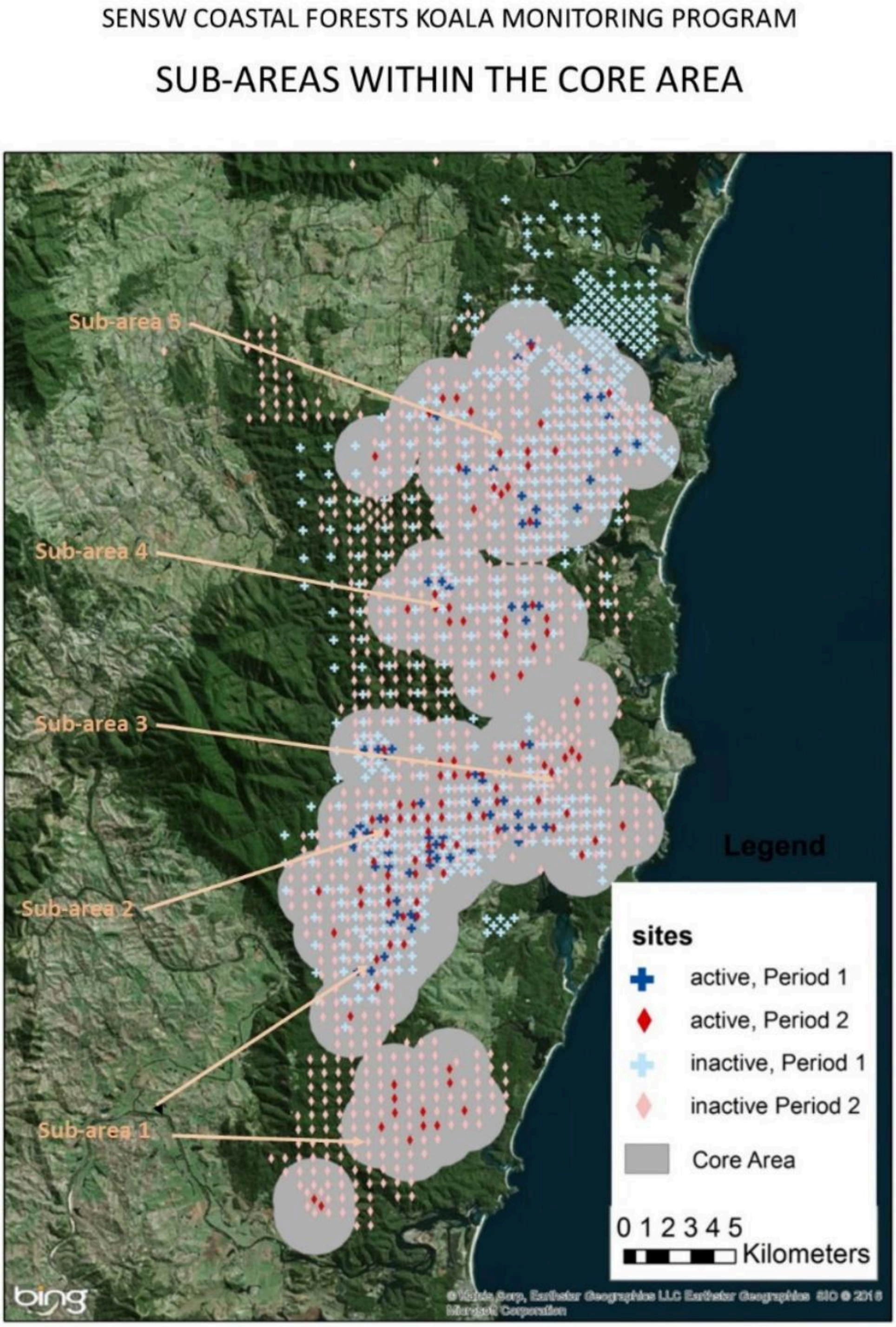

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Figure 1: Map of the sampled locations and their activity for the two initial sampling periods. The derived core area and 5 sub-areas are also shown. In total 979 sites of the 500 x 500 m grid are located within the core area.

Data management and analyses

Data was gathered electronically and uploaded into a database specifically designed for koala survey and monitoring in SENSW. A programming tool (*ikoala*) [17] was developed by University of Canberra biometricians and linked to this database, the statistical package 'R', and Google mapping software. This provided the capacity to automatically generate reports estimating koala occupancy rates in three designated survey periods using a Bayesian-based occupancy modelling approach.

This site-occupancy estimate was based the proportion/percentage of sites that are active but allows for imperfect detection of koala activity. Two parameters are estimated using this approach. The first is psi, the proportion of sites that are occupied adjusted for imperfect detection[18] and p, the probability of detection given that koala faecal pellets are present. To obtain its estimate of p, each actual site visit is treated as three repeated visits with 10 trees being searched as a part of each repeated visit. This step is required as the estimation of p requires temporally repeated visits to the same site with the assumption that there is no change in population size or activity levels between visits. Testing with varying numbers of trees being searched during the repeat visits was performed with only limited effects on the estimate of p.

The site occupancy was calculated as the proportion of sites recorded as active in each period, adjusted to allow for imperfect detection. The adjustments included: a) an increased proportion of sites designated as occupied (*psi*); and, b) an increased probability of detection if koala faecal pellets were present (p). Additional information about this analysis method is provided Appendix 2.

In its automatically generated reports *Ikoala* also maps koalas' distribution, activity level contours and tree species and size-class preferences. Indicative *ikoala* monitoring results are provided in the Results and Appendices sections of this document.

Results

Summary of results provided in this reportr

The indicative results shown below and in Appendices 2a & 2b are derived from *Ikoala*-generated report analysing data gathered from all 5 sub-areas in the three periods. These include:

- the grid-sites assessed and presence/absence results for all periods;
- a summary of koala occurrence at grid-sites that were assessed in all specified periods;
- a summary of the numbers of sites within the core area that were monitored and those that were not monitored during each period, and the number of monitored sites where evidence of koalas was located;
- mapped results per period;
- summary output of occupancy model.

Ikoala-generated indicative results all sub-areas combined are provided below, ad for sub-areas 2 and 4 for the three periods are provided in Appendices 2a and 2b of this report.

Figure 1 below shows the ikoala-generated map of the study area, grid-sites assessed and presence/absence results for all periods.

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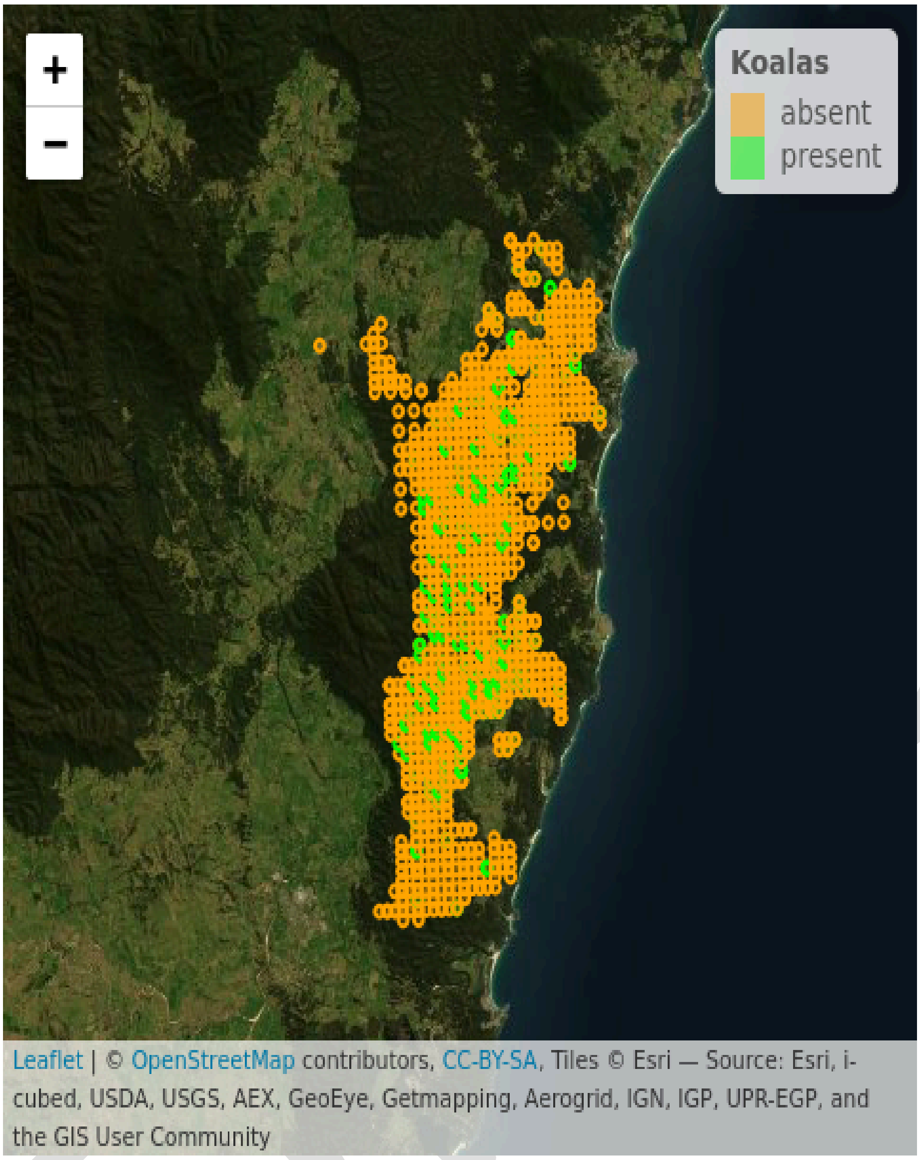
[17] Bernd Gruber & Aaron T. Adamack (2015). Koala Poo Survey – Report. University of Canberra, ACT

[18] Bernd Gruber & Aaron T. Adamack (2014). SENSW Coastal Forests Koala Survey 2012-2013 Analysis of occurrence, activity and tree preference – Report. University of Canberra, ACT



Koala occurrence

Table 2 provides the *ikoala*-generated summary of the presence/absence of koala evidence at grid-sites in all sub-areas within the study area that were assessed in the three specified periods.

Table 2: *Summary of* the presence/absence of koala evidence *at grid-sites within the study area that were assessed in the three specified periods.*

	Count and proportion
Visited sites	1545
Active sites	219 (14.2 %)
Inactive sites	1326 (85.8 %)
Examined trees	46147
Active trees	556(1%)
Inactive trees	45591(99%)
Trees at active sites	6570(14%)
Trees at inactive sites	39577(86%)

Monitoring sites and koala evidence

Table 3 below provides an *ikoala*-generated summary of the numbers of sites within the core area that were monitored and those that were not monitored during each period, and the number of monitored sites where evidence of koalas was located.

Table 3: *ikoala-generated summary of the numbers of sites within the core area that were monitored and those that were not monitored during each period, and the number of monitored sites where evidence of koalas was located. Please note that sites within were moved to corresponding monitoring sites. Sites visited more than once during a period were combined into one observation.*

	Period 1 (2007-10)	Period 2 (2011-15)	Period 3 (2016-19)
absent	384	675	267
present	63	101	55
not monitored	1119	790	1244
Sum	1566	1566	1566

Presence/absence proportions

Table 4 shows the percentage of sites where koala evidence was located for each study period

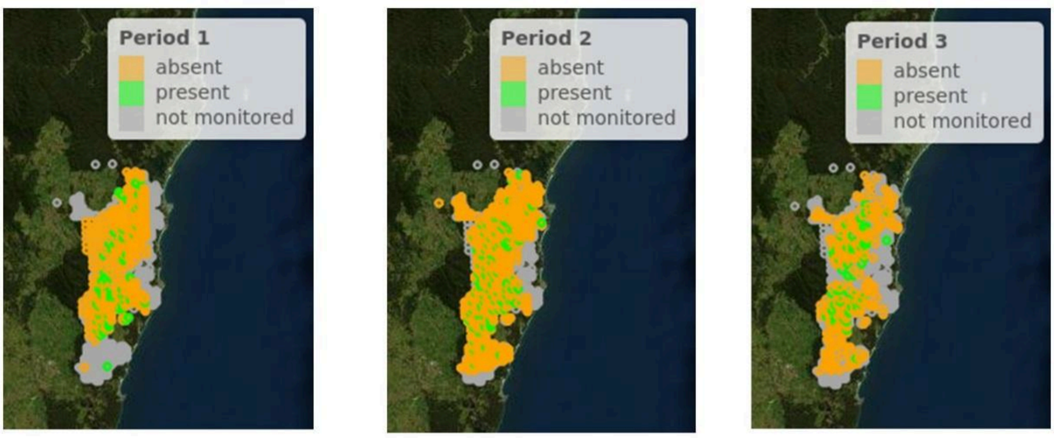
Table 4: *Percentage of sites where koala evidence was located for each study period*

	Period 1	Period 2	Period 3
absent [%]	86	87	83
present [%]	14	13	17
Sum	100	100	100

Mapped results per period

Figure 2, below, shows the *ikoala*-generated maps of the grid-sites that were assessed in each monitoring period and their presence/absence results.

MONITORING RESULTS FOR THE STUDY AREA FOR THE THREE PERIODS



Estimated occupancy over time and probability of detection

A Bayesian-based occupancy modelling approach was used to estimate site occupancy. Site occupancy is analogous to the proportion/percentage of sites that are active, but accounts for imperfect detection of koala evidence. Two parameters are estimated using this approach. The first is *psi*, the proportion of sites that are occupied adjusted for imperfect detection and *p*, the probability of detection given that koala faecal pellets are present. To obtain our estimate of *p*, we treat each actual site visit as three repeated visits with 10 trees being searched as a part of each repeated visit. This step is required as the estimation of *p* requires temporally repeated visits to the same sight with the assumption that there is no change in population size or activity levels between visits. We have performed testing with varying numbers of trees being visited during the repeat visits and have found that it has only limited effects on the estimate of *p.*

Summary output of occupancy model

Table 5 below consists of the following parameters:

- the occupancy rate for Periods (P) 1 – 3
- the number of active sites in each period
- the probability that koala pellets would be detected if they were present at a grid-site
- the probability that a grid-site unoccupied in Period 1 is occupied in Period 2 (site colonisation rate)
- the probability that a grid-site occupied in Period 1 would be unoccupied in Period 2 (site extinction rate).

In regards the last two columns: 2.5% indicates the measure in which the mean of the parameter will be less than the 2.5% figure 2.5% of the time in a random selection of sites, and 97.5% indicates the mean of the parameter will be less than the 97.5% figure 97.5% of the time in a random selection of sites.

Table 5: *Summary output of occupancy model.*

	mean	sd	2.5%	97.5%
occupancy rate[P1]	0.16	0.013	0.135	0.187
occupancy rate[P2]	0.165	0.012	0.143	0.189
occupancy rate[P3]	0.175	0.017	0.144	0.21
# occupied sites[P1]	250	15	222	282
# occupied sites[P2]	257	11	236	280
# occupied sites[P3]	273	22	233	318
detection probability at a site (30 trees)	0.873	0.014	0.845	0.898
colonisation rate[P1-2]	0.132	0.013	0.109	0.158
colonisation rate[P2-3]	0.111	0.018	0.078	0.148
extinction rate[P1-2]	0.336	0.043	0.255	0.424
extinction rate[P2-3]	0.501	0.047	0.41	0.593
probability of increase[P1-2]	0.614	0.487	0	1
probability of increase[P2-3]	0.712	0.453	0	1

Figures 3 and 4, below show the percentage of occupied sites over the three periods and the Predicted number of sites occupied over periods out of a total of 1566 sites

Figure 3: *Percentage of occupied sites over the three periods*

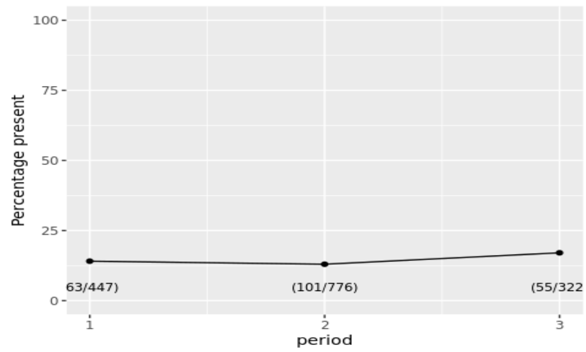
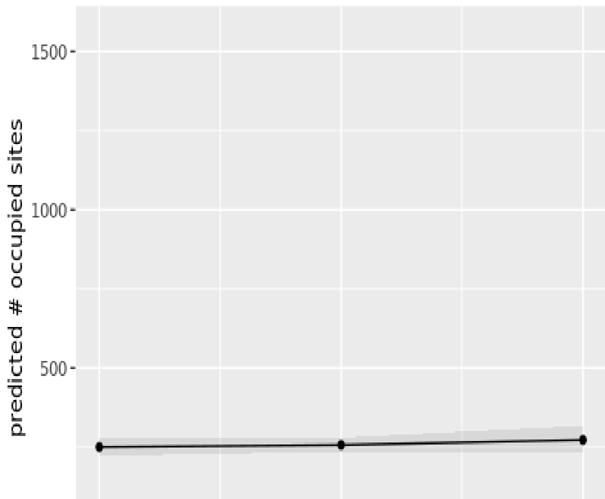


Figure 4: Predicted number of sites occupied over periods (out of a total of 1566



Discussion

Community engagement

Community engagement has been a key component of the monitoring program. Community-based contractors including those from Local Aboriginal Land Councils, with the support of local volunteers, have undertaken almost all the fieldwork for this monitoring program.

Trends revealed in the results

The monitoring program's results to date indicate:

- Sub-area occupancy rates range from 11.2% (Sub area 4) to 22.4% (Sub area 2) and average approximately 15% over the whole study area. These rates continue to be low, compared with those from other regions where surveys using the same method have been undertaken (See Table 6 below).
- There has been no discernible (ie >30%) increase or decrease in koala occupancy rates in any of the 4 sub-areas assessed in Period 3 when compared with previous periods.
- Occupancy rates in one sub-area (Sub area 1) may have increased, however fieldwork is still to be completed in this area. Those in two sub-areas (2 and 3) appear to be remaining relatively stable, those in two sub-areas (4 and 5) may have declined. However, the 90-95% confidence threshold established by Gruber and Aalmack[19] that would confirm these trends was not achieved.

Table 6: Study area occupancy rates compared with those from other regions where surveys using the same method have been undertaken

Date of survey	Study Area	#Sub-Area	Approx. Area	Occupancy Rate
2014	Strzelecki Ranges[20]	All	3,250 ha	75%
2014	S. Tablelands[21]	All	120,000 ha	45%
2017	S. Tablelands[22]	3	20,000 ha	76%
2016	Coastal	2	5,000 ha	22.5%
2017	Coastal	4	5,000 ha	11%

The results suggest that: a) koala numbers remain low; b) there has not been a significant increase in koala occupancy. This conclusion differs from that of Jurskis (2016) who states the population *is clearly in a phase of irruption*.

The tree species preference analyses

The tree species preference analyses underpinning *ikoala* also helped guide the review of koala tree use (Office of environment and Heritage 2018)[23] in the South Coast and Southern Tablelands KMA that contributes to the development of the NSW Koala Strategy's Koala Habitat Suitability Models, the purpose which is to measure koala habitat suitability at any location across NSW.

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[19] *Ibid*

[20] Office of Environment and Heritage (unpublished data)

[21] Allen C. (2014). *Towards a Comprehensive Koala Plan of Management for North East Monaro -Koala Habitat Study.* Unpublished report. Chris Allen Office of Environment and Heritage. PO Box 656 Merimbula NSW 2550.

[22] Office of Environment and Heritage (unpublished data)

[23] Office of environment and Heritage (2018). A review of koala tree use across NSW. NSW Office of Environment and Heritage. ISBN 978-1-92575-420-9 ID OEH20180385. https://www.environment.nsw.gov.au/research-and-publications/publications-search/a-review-of-koala-tree-use-across-new-south-wales

The efficacy of Regularised Grid-based Spot Assessment Technique

For the past decade the Regularised Grid-based Spot Assessment Technique **(**RGb-SAT) has been the foundational koala survey and monitoring tool in SENSW, where, in this part of the koala's range, only low-density populations occur. From the conflicting interpretations of the koala's conservation status and habitat needs that were the norm 20 years ago and the consequent impotence around management, the method has provided common ground for agencies and community organisations to work together improve knowledge, monitor and manage koala populations.

Although the method has been criticised in Woosnam – Merchez (2013[24]), much of this criticism appears based on a lack of understanding of the methods and the validated knowledge that has been gained through its application (Phillips and Callaghan 2014)[25]. Given the extent of the survey and monitoring work in south eastern NSW using this method, the results can provide an informative contribution to evaluating the efficacy of this method.

Passive acoustic survey

In the late spring of 2016 FNSW scientists undertook a passive acoustic survey where recording devices were placed at 24 of the study area's grid-sites for two weeks, 12 to the north and 12 to the south of the Murrah River. Koala bellows were recorded 522 times at 21 out of the 24 sites, with one site yielding 120 calls (Law et al submitted)[26].

Comparing the passive acoustic surveys with pellet surveys at the same sites revealed a broadly consistent pattern between the two methods discussed above, with greater levels of koala activity recorded immediately to the south of the Murrah River (Sub-areas 2 & 3), compared with the sub-area (4) immediately to the north.

However, acoustic surveys had site detection rates more than three times higher than that of the pellet surveys, which likely reflects the greater area sampled at each site by acoustic recording (~ 300 m radius Law et al. unpubl. data) than localised grid-site surveys. Acoustic surveys appear to be more cost effective than pellet surveys over an equivalent area and they are particularly effective at detecting low density koala populations.

Passive acoustic surveys have since been undertaken in the remaining sub-areas at approximately the same time as the RBb-SAT monitoring fieldwork. The results are not available at this stage.

Monitoring program review

The passive acoustic survey results from Sub-areas 2 and 4 appear to indicate that these are more cost effective than pellet surveys in ascertaining occupancy rates and contributing to a koala monitoring program. However, further research will be needed to quantify the levels of confidence that variations in bellowing rates indicate changes in occupancy rates. On the other hand, pellet surveys are not restricted to the koala breeding season, potentially provide information on koala

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[24]Woosnam – Merchez, O., Cristescu, R., Dique, D., Ellis, B., Beeton, R. J. S., Simmonds, J., and Carrick, F. 2013. *What faecal pellet surveys can and can't reveal about the ecology of koalas Phascolarctos cinereus.* Australian Zoologist36 (2) 192 – 200.

[25] Phillips S. and Callaghan J. (2014). *What faecal pellet surveys can really reveal about the ecology of koalas.* Biolink Technical Report. https://www.biolink.com.au/publications

[26] Law, B.1, Gonsalves, L., Bilney, R., Peterie, J., Pietsch, R., Roe, P.4 and Truskinger, A. (Submitted). *Using Passive Acoustic Recording and Automated Call Identification to Survey Koalas in the Southern Forests of New South Wales.* Forest Science Unit, NSW Department of Primary Industries, Locked Bag 5123, Parramatta, NSW 2124, Australia, Email: brad.law@dpi.nsw.gov.au

disease status, diet and genetic diversity and provide capacity to continue to collect ecological data at grid-sites for monitoring analyses, and surveys.

Given the outcomes and issues above, the program managers have committed to a broad-ranging and consultative monitoring program review that will include a cost-benefit analysis of monitoring methods including those discussed above and others undertaken elsewhere in NSW. The potential contribution provided by improved technologies and data analytics, including further analysis of the data already gathered, will also be considered.

Genetic studies by Koala Health Hub (Sydney University)

A genetic and disease study[27] was undertaken by the Koala Health Hub (University of Sydney) in the study area in Period 3 that also provided information that informs the monitoring program results.

Key technical outcomes of the study were:

- advances in obtaining useable DNA over a greater range of scat quality;
- advances in assays for use on highly fragmented DNA from older scats;
- quantified sensitivity of chlamydial PCR for various levels of scat quality;
- confirmed concordance of fresh scat-based and swab-based chlamydial qPCR.

Key ecological outcomes were:

- *Chlamydia pecorum* appears likely to be absent from sub areas 1, 2 and 3 (approx. 80% certainty) but is present in sub areas 4 and 5, and in Kooraban NP.
- The 100% prevalence of Koala retrovirus A, typical of Qld and NSW koalas, extends to this population. The study was unable to able to comment on presence/ absence of KoRV B.
- The observed sex ratio was approx. 3 males to 4 females if joeys excluded. Three female-joey pairs were identified.
- There was some, but limited, mitochondrial DNA diversity within sub areas 2 and 3, with absence of genotypes from nearby Southern Tablelands and Mallacoota, but similarity to a genotype from Tubbut, Victoria; suggestive of past founder effects and/or genetic drift in the sub areas 2 and 3 populations.

Current management initiatives

Other ecological data, including evidence of other fauna species, fuel-hazard loads, regrowth species and density and eucalypt canopy condition, were recorded at each grid-site. These are providing the capacity to:

- support the Environmental Trust-funded Indigenous Firesticks Network cultural burning program in the Murrah Landscape in regards site selection and monitoring, particularly in assessing and recording changes to koala habitat quality at locations where cultural burning is undertaken;
- assist implementation of adaptive management actions committed to in the Murrah Flora Reserves Plan of Management[28], including contributing information to the Koala Rehabilitation Project (also funded through the Saving our Species program) regarding ecological changes in areas adjoining research plots;
- contribute a foundational dataset to potential eucalypt dieback and regeneration monitoring programs

[27] Damien Higgins, David Phalen, Andrea Casteriano, Mark Krockenberger (2017). Management of Small, Isolated, Coastal Population of Koalas in Southeast New South Wales: Final Report. June 2017. Koala Health Hub, The University of Sydney.

[28] *Ibid* Office of Environment and Heritage (2018). Murrah Flora Reserves Draft Final Plan of Management

- provide data to assist fuel hazard burn planning (and associated risk-minimisation to koalas) and wild-fire response decision-making to OEH staff and the NSW Rural Fire Service.

Other management initiatives to support the conservation of the SENSW coastal forests koala population include:

1. reviewing the current monitoring program as discussed above and implementing the outcomes of the review;
2. improving the management of fire, including supporting the introduction of cultural burning into the landscape;
3. continuing the research into the rehabilitation of degraded logging regrowth;
4. planting of locally endemic koala browse species on adjoining private lands;
5. support for a strong, knowledgeable and effective community voice for local koalas.

Some conclusions

The koalas of the SENSW coastal forests are important because of their geographic location within the wider spread of koalas across Australia, genetics (unique allelles), habitat use, history, and the level of stakeholder commitment to its conservation. Monitoring such a small and widely scattered koala population is challenging.

The approaches discussed here all contribute to our knowledge of these koalas, and levels of confidence in trends indicated in data analyses will increase as more data is gathered. Technologies and data analytic capacities associated with the monitoring are developing rapidly and these may determine profound changes in how the program is undertaken; for example, the capacity to distinguish recorded bellows from individual animals, if that were possible, would significantly improve the monitoring capacity of the passive acoustic survey method.

The NSW Koala Strategy poses the perhaps ambitious *vision to stabilise then increase koala numbers over the longer-term, ensuring genetically diverse and viable populations across the state.* In the south eastern corner of the state, koala numbers remain low and the future of the population is not secure, despite changes to reserve status of its habitat and the removal of the threat of intensive logging across much of the habitat sustaining the population.

Given the above what we do and do not do in regards this population is a litmus test for the NSW Koala Strategy vision. Ongoing monitoring, although challenging, is critical because only with this can: a) critically needed evaluation and adaption of current management strategies occur; and b) we can report whether the Koala Strategy's vision has been achieved in regards this population.

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APPENDIX 1: Development of koala monitoring methods in SENSW coastal forests study area

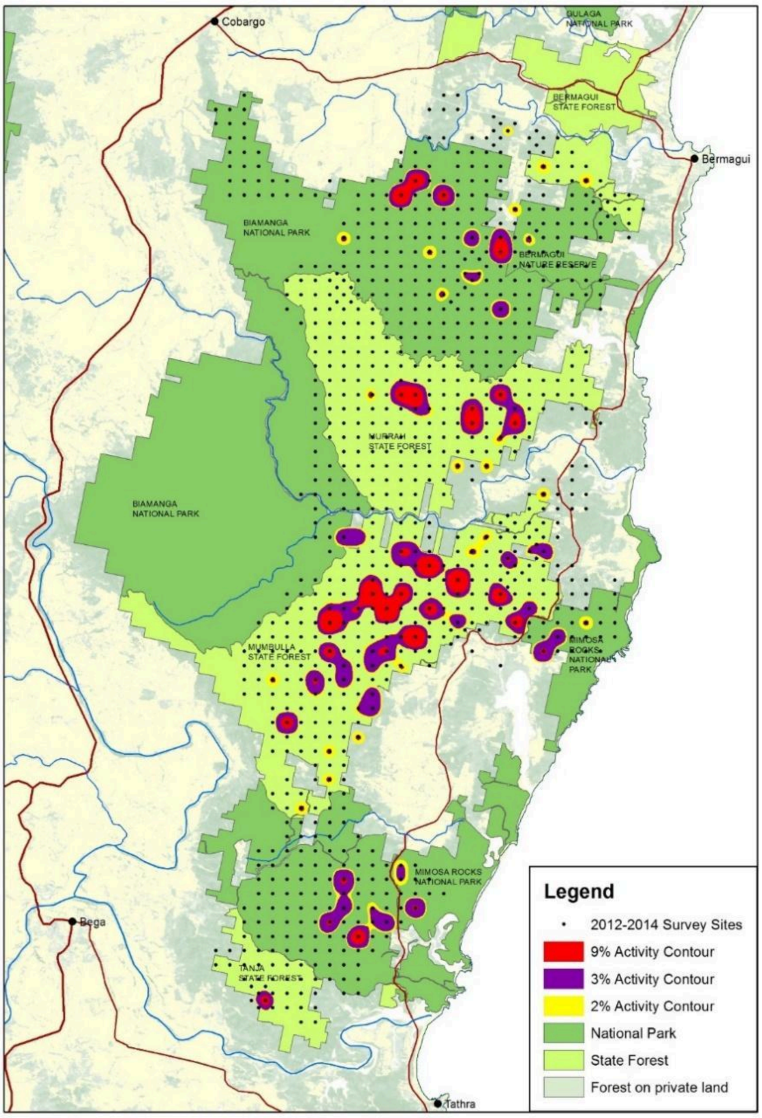
<u>Establishing the foundations</u>

The *Corridors and Core Habitat for Koalas* (CCH) *Project* was a 6-year cross-tenure landscape initiative that commenced in 2012 aiming to protect, enhance and connect habitat sustaining the last known koala population in NSW Far South Coast forests. It is sponsored by the Australian Government's Biodiversity Fund and managed by the NSW Office of Environment and Heritage. One of the project's main objectives is to develop a koala monitoring program to ascertain distribution changes and population trends and provide the results to help guide management strategies supporting the recovery potential of the population.

In 2012-14 the CCH project undertook an extensive survey to assess koala distribution, abundance and tree species preferences across a 30,000 ha study area, using the Regularised Grid-based Spot Assessment Technique (RGb-SAT) method (Office of Environment and Heritage 2015) and building on a previous survey undertaken in 2007-2009 (Department of Environment Conservation and Water 2010).

The distribution of grid-sites and their activity levels derived from the are shown in Figure 1, right.

The results from the two surveys provided sufficient consistency in terms of the location of higher-use areas and tree species preferences to inform land management decisions in regards hazard control, logging and koala habitat rehabilitation.



[29] Aaron T. Adamack, Veronika Vysna & Bernd Gruber (2016). *Comparison of Koala Surveys in South-Eastern NSW Coastal Forests 2007-2009 & 2010-2013 Analysis of occurrence, activity and tree preference –Report.* University of Canberra, ACT.

The question remained as to the extent the foundational datasets that had been established using the the RGb-SAT method could contribute to an ongoing population monitoring program.

<u>The first comparative analysis</u>

Adamack et al (2016)[30] analysed the results from the surveys discussed above, separating those from the northern and southern portions of the study area, as well as the combined results from both portions. These separate analyses were undertaken because the results from the southern portion indicated a greater concentration of koala activity clusters, and a higher and increasing proportion of active sites and higher site activity, whilst koala activity clusters in the northern portion were smaller and more scattered.

For the comparison between sampling programs, they restricted their analyses to a subset of sites for which they could find spatial pairs of sites between the two sampling programs. Spatial pairs consisted of two sites (one site from the 2007-2009 sampling program and one site from the 2010-2013 sampling program) that were located within 500 m of one another. If there were multiple potential pair candidates for a site, they chose the site that was closest to the initial site so that each site had only a single pair. The complete set of sampling locations is shown in Figure 2.

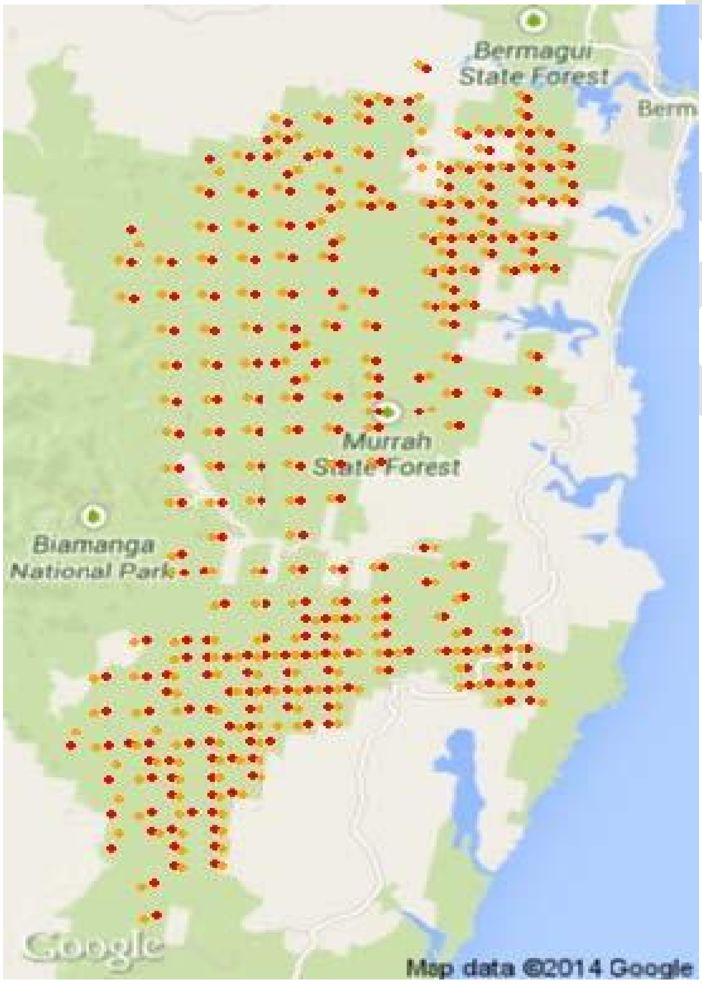


Figure 4. Location of the paired survey sites from the 2007-2009 and 2012-2014 surveys used for comparative analysis by the University of Canberra.

[30] Ibid. *Comparison of Koala Surveys in South-Eastern NSW Coastal Forests*.

In regards the northern portion of the study area the percentage of sites that were active increased marginally from 6% of sites (8 sites total) in 2007-2009 to 8% of sites (11 sites total) in 2010-2013. Over the same period, the number of active trees significantly increased (Chi-square test, p = 0.017), more than doubling from 14 to 31 active trees. The location and intensity of koala activity shifted between the two surveys. During the 2007-2009 survey, there were two isolated main areas of whereas during the 2010-2013 survey, there were three main areas of koala activity and the level of koala activity appeared to be higher. Comparing the distribution of koala activity in the two periods, active sites during the 2007-2009 survey tended to only have 1 or 2 active trees whilst active sites during the 2010-2013 survey often had several active trees.

In regards the southern portion of the study area, thirty active sites (15% of all sites) were active during the 2007-2009 survey while 41 sites were active (23%) during the 2010-2013 survey. Koala activity during the 2007-2009 survey was widespread, but at low levels, with many isolated areas of activity. During the 2010-2013 survey, koala activity was concentrated in the north and central part of this portion of the study area. During the 2007-2009 survey, active sites typically had only 1 to 2 trees and at most 6 trees with koala activity, whilst in the 2010-2013 survey, koala activity tended to be higher with sites typically having 2 to 4 active trees and as many as 15 active trees.

Detectability Study

In order to inform the design a robust monitoring scheme for koala populations Gruber & Aaron Adamack 2014[31] undertook an experiment to estimate the overall detection probability of koala faecal pellets (kfp) when searched for using the RGb-SAT method.

To determine the detection probability of finding a kfp using this method, known numbers of kfp were placed under trees in a forested area that was known to be unused (or only lightly used) by koalas, but in the vicinity of known koala populations. 1216 kfp were "hidden" under a total of 425 trees, each tree having a minimum diameter at breast height (dbh) of 15 cm. They used five different levels of kfp hidden under trees (0=no pellet, 1, 2, 4 or 8 pellets) in order to represent a range of koala usage levels across trees (e.g. 0 pellets under a tree represented an unused tree, 8 pellets represented a heavily used tree). In order to have a close to balanced statistical design, they attempted to prepare an equal number of trees for each level of kfp (actual percentages of trees within each level: 17 - 22 percent, Table 1).

Factors that significantly affected the detection probability of kfp were the number of pellets placed and the identity of the searcher. Searcher experience and site difficulty did not have a significant effect on detection probability. Inexperienced searchers were not limited in the amount of time they had to search under each tree. Ignoring the differences in search protocols implemented by inexperienced and experienced searchers, the overall detection probabilities between both groups were quite similar.

The overall detection probability for 1 or more kfp under a tree across all combinations of searcher experience and search method used was 0.64, which based on expert opinion was thought to be low. Factors that could have contributed to this result included dense vegetation understory and ground-cover in the area where the experiment was undertaken, and wet conditions following heavy rain before and intermittent rain during the study.

The study concluded, there was a high probability of overlooking koala faecal pellets and thus estimates on the occurrence of koalas will be negatively biased (e.g. be underestimates). The time to

[31] Gruber & Aaron Adamack 2015. *Koala Poo Survey*

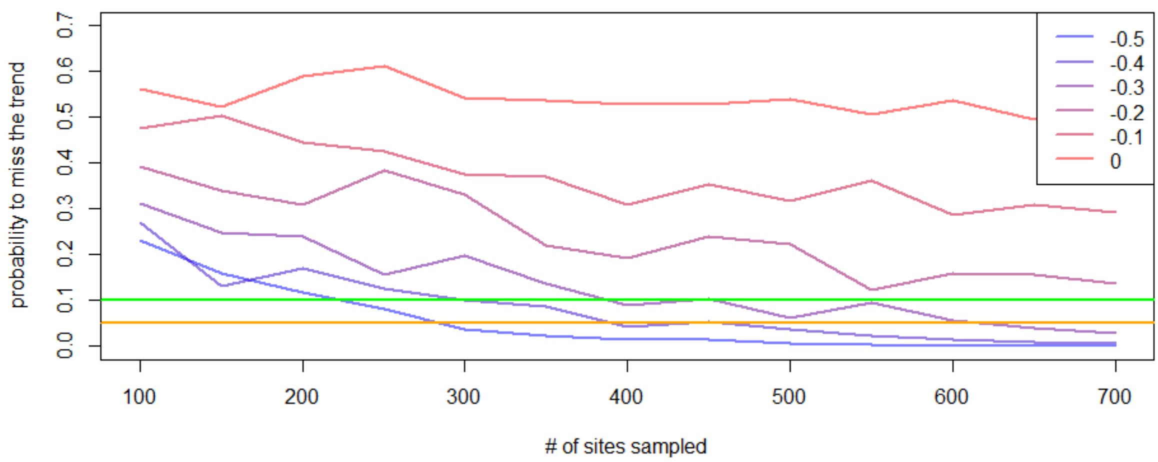
first detection in 95% of the successful searches by experienced searchers was less than 6 minutes and there was no gain in searching for longer than 8 minutes.

The study was undertaken in worse conditions that would normally be undertaken, giving certainty that confidence levels derived from its results would be achieved when applied in the field.

The RGb-SAT method requires 30 trees be sampled at each site. From previously collected monitoring data, Gruber and Aalmack calculated the detection probability for the overall plot of 30 trees, assuming there is a single pellet below 1-10 trees. The detection probability for a single pellet under a single tree is: *0.475* and if there are only five trees with a single pellet each in the entire plot of 30 trees, the method would detect the presence of kfp with a detection probability >0.95.

<u>Quantifying probabilities of detecting a decline or increase</u>
In a subsequent analyses of the results Gruber and Aalmack (2016)[32] estimated koala occupancy rates in the study area based on data from the two sampling periods using a Bayesian[33] occupancy modelling approach. The resulting rates of occupancy were used in a simulation to mimic scenarios of population change from a severe decline to a very substantial increase in occupancy. For these scenarios they estimated the probability to find the simulated trend or in statistical terms the power to detect an increase/decline for varying sampling efforts. With certain caveats they interpreted the results from the 2007-9 and 2012-14 as indicating there was a 76% chance that these indicated an increase in the koala occupancy between the two periods. The often-used threshold of 95% certainty of increase would have not been achieved.

Gruber and Aalmack also plotted the probabilities that a decline or increase would be detected, depending on the sampling intensity (100 to 700 sites) and the extent of change in occupancy. (Gruber pers. comm.) The results are shown in Figure X below where the x_axis shows the number of sites sampled and the y axis shows the probability of not detecting a decline given the decline indicated by the color. By way of example these analyses indicated that if 500 grid-sites there would a 6% chance to miss a 30% decline.



[32] Bernd Gruber & Aaron Adamack (2016). *Draft report to inform the sampling effort of the Koala monitoring programme around Bega.* University of Canberra. ACT.
[33] An algebraic procedure to calculate the probabiltity that the trends discerned in data are correct.

An occupancy model termed a *multiseasonal single species occupancy model* was also developed from the data[34]. This consisted of four parameters:

- the occupancy rate
- the probability that koala pellets would be detected if they were present at a grid-site
- the probability that a grid-site unoccupied in Period 1 would be occupied in Period 2
- the probability that a grid-site occupied in Period 1 would be unoccupied in Period 2.

Multiple surveys within sampling periods (also called seasons) were assumed in order to estimate a detection probability. Presence/absence data from the 30 trees from each grid-site were subdivided into random subsamples of 10 trees, resulting in 3 surveys per location (K=3). The dataset consisted therefore of 2 seasons (periods) and 3 surveys per season. The activity pattern within the core area was used to estimate occupancy rates using a Bayesian approach (Table 3). An important derived parameter was the probability of a significant change in occupancy rate between seasons.

The occupancy of sites was varied from -100 to +100, meaning the most severe scenario was an estimate of only 58 occupied sites (158-100) and the most optimistic scenario was an increase of +100 additional sites occupied (258). The sampling effort was varied from 100 to 900 sites in steps of hundreds, resulting in 21 x 9 scenarios. Each scenario was repeated a hundred times and the average power to detect the change was calculated. Figure 4 below shows the probability for the levels of sampling effort and simulated trends.

	occupancy trend																				
sampling effort	-100	-90	-80	-70	-60	-50	-40	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100
100	0.159	0.118	0.133	0.193	0.321	0.289	0.292	0.431	0.46	0.566	0.511	0.607	0.618	0.743	0.734	0.74	0.814	0.817	0.817	0.899	0.887
200	0.015	0.024	0.06	0.1	0.09	0.176	0.251	0.369	0.281	0.445	0.516	0.667	0.596	0.732	0.682	0.79	0.867	0.847	0.945	0.939	0.964
300	0.007	0.01	0.037	0.027	0.065	0.135	0.225	0.242	0.395	0.459	0.61	0.605	0.647	0.733	0.697	0.855	0.883	0.914	0.966	0.993	0.979
400	0.001	0.002	0.004	0.009	0.027	0.08	0.146	0.178	0.423	0.47	0.477	0.593	0.753	0.825	0.855	0.924	0.937	0.971	0.989	0.991	0.991
500	0	0.006	0.001	0.011	0.005	0.043	0.114	0.123	0.262	0.373	0.482	0.605	0.787	0.822	0.856	0.959	0.967	0.988	0.978	0.976	0.997
600	0	0	0	0.002	0.007	0.032	0.066	0.166	0.28	0.338	0.559	0.563	0.787	0.873	0.94	0.96	0.979	0.986	0.997	0.999	1
700	0	0	0	0.001	0.006	0.021	0.044	0.105	0.273	0.342	0.438	0.712	0.795	0.88	0.943	0.955	0.988	0.995	0.997	0.999	1
800	0	0	0	0.001	0.004	0.005	0.035	0.085	0.168	0.324	0.518	0.601	0.793	0.884	0.943	0.984	0.993	0.998	1	1	1
900	0	0	0	0	0.001	0.009	0.025	0.074	0.164	0.321	0.53	0.665	0.857	0.905	0.919	0.993	0.995	1	1	1	1

Figure 4

<u>Developing a monitoring strategy</u>

Following a review of the analyses above, and the potential for long-term funding from the Saving our Species Program to continue the monitoring program, we concluded an ensuing phase of monitoring could be undertaken, building on the foundational dataset and analyses that had been undertaken.

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[34] Gruber and Adamack 2016

APPENDIX 2a: Results generated by *Ikoala* for Sub Area 2

Koala occurrence

Table 2 provides a summary of koala occurrence at grid-sites within the study area that were assessed in all specified periods.

Table 2: *Summary of koala occurrence at grid-sites within the study area that were assessed in all specified periods.*

Table 2: *Summary for occurrence of koalas within the study area*

	Count and proportion
Visited sites	331
Active sites	77 (23.3 %)
Inactive sites	254 (76.7 %)
Examined trees	9843
Active trees	199(2%)
Inactive trees	9644(98%)
Trees at active sites	2310(23%)
Trees at inactive sites	7533(77%)

Monitoring sites and koala evidence

Table 3 provides a summary of the numbers of sites within the core area that were monitored and those that were not monitored during each period, and the number of monitored sites where evidence of koalas was located.

Table 3: *Summary of the numbers of sites within the core area that were monitored and those that were not monitored during each period, and the number of monitored sites where evidence of koalas was located. Please note that sites within were moved to corresponding monitoring sites. Sites visited more than once during a period were combined into one observation.*

	Period 1	Period 2	Period 3
absent	61	103	90
present	22	32	23
not monitored	71	19	41
Sum	154	154	154

Percentage of occurrences

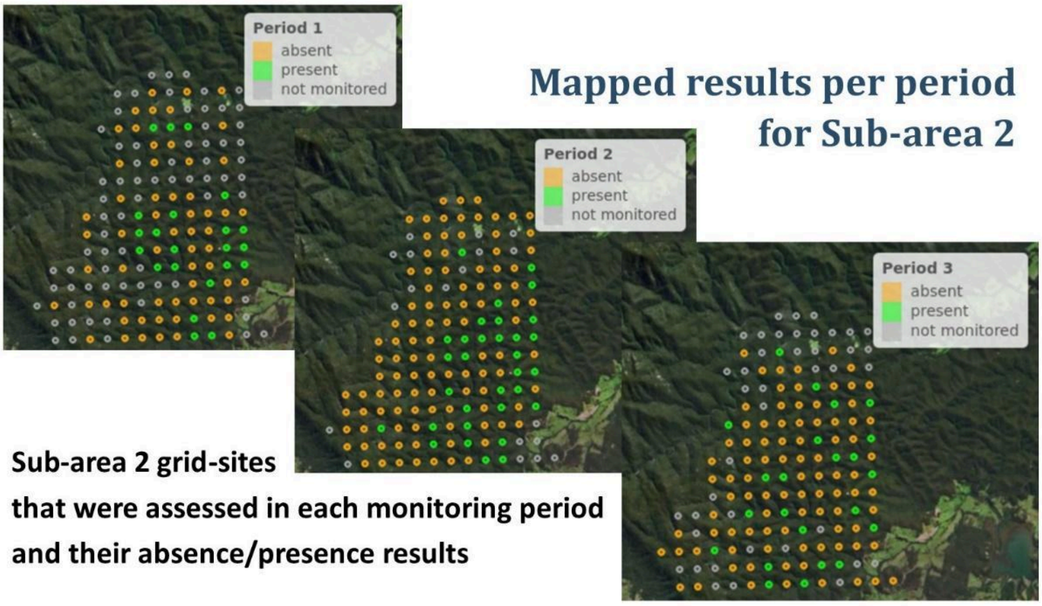
Table 4 provides the percentage of occurrences of koalas per study period

Table 4: *Percentage of occurrences of koalas per study period*

	Period 1	Period 2	Period 3
absent [%]	73	76	80
present [%]	27	24	20
Sum	100	100	100

Mapped results per period

The figures below show the grid-sites that were assessed in each monitoring period and their koala presence/absence results.



Estimated occupancy over time and probability of detection

A Bayesian-based occupancy modelling approach was used to estimate site occupancy. Site occupancy is analogous to the proportion/percentage of sites that are active, but accounts for imperfect detection of koala activity. Two parameters are estimated using this approach. The first is *psi*, the proportion of sites that are occupied adjusted for imperfect detection and *p*, the probability of detection given that koala faecal pellets are present. To obtain our estimate of *p*, we treat each actual site visit as three repeated visits with 10 trees being searched as a part of each repeated visit. This step is required as the estimation of *p* requires temporally repeated visits to the same sight with the assumption that there is no change in population size or activity levels between visits. We have performed testing with varying numbers of trees being visited during the repeat visits and have found that it has only limited effects on the estimate of *p*.

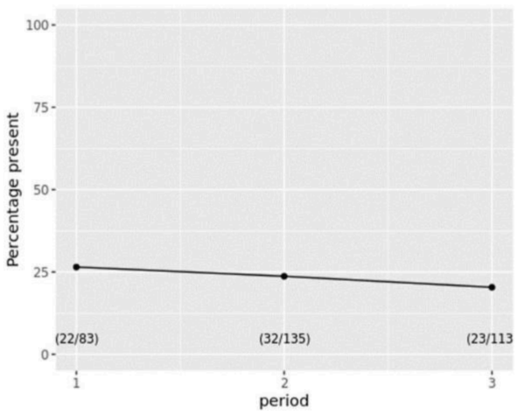


Figure 3: *Percentage of occupied sites over the three periods*

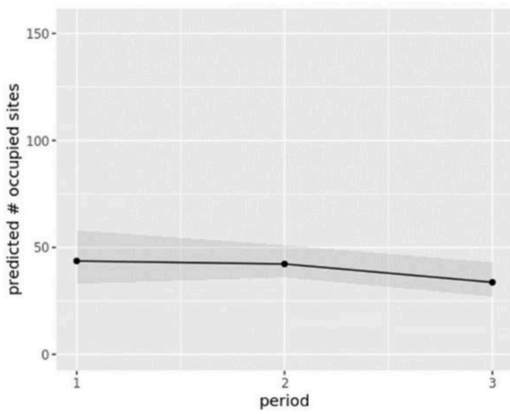


Figure 4: *Predicted number of sites occupied over periods (out of a total of 154 sites)*

Summary output of occupancy model

Table 5 below consists of the following parameters:

- the occupancy rate at each period
- the number of occupied/active sites in each period
- the probability that koala pellets would be detected if they were present at a grid-site
- the probability that a grid-site unoccupied in a period and is occupied in the following period (site colonisation rate)
- the probability that a grid-site occupied in a period would be unoccupied in the following period (site extinction rate).

In regards to the last two columns: 2.5% indicates the measure in which the mean of the parameter will be less than the 2.5% figure 2.5% of the time in a random selection of sites, and 97.5% indicates the mean of the parameter will be less than the 97.5% figure 97.5% of the time in a random selection of sites.

Table 5: *Summary output of occupancy model.*

	mean	sd	2.5%	97.5%
occupancy rate[P1]	0.287	0.055	0.189	0.402
occupancy rate[P2]	0.279	0.043	0.201	0.369
occupancy rate[P3]	0.226	0.042	0.15	0.314
# occupied sites[P1]	44	6	33	58
# occupied sites[P2]	42	4	36	51
# occupied sites[P3]	34	4	27	43
detection probability at a site (30 trees)	0.867	0.033	0.794	0.922
colonisation rate[P1-2]	0.191	0.05	0.102	0.296
colonisation rate[P2-3]	0.125	0.046	0.045	0.225
extinction rate[P1-2]	0.503	0.116	0.288	0.741
extinction rate[P2-3]	0.485	0.097	0.303	0.681
probability of increase[P1-2]	0.459	0.498	0	1
probability of increase[P2-3]	0.139	0.346	0	1

APPENDIX 2b: Results generated by *Ikoala* for Sub Area 5

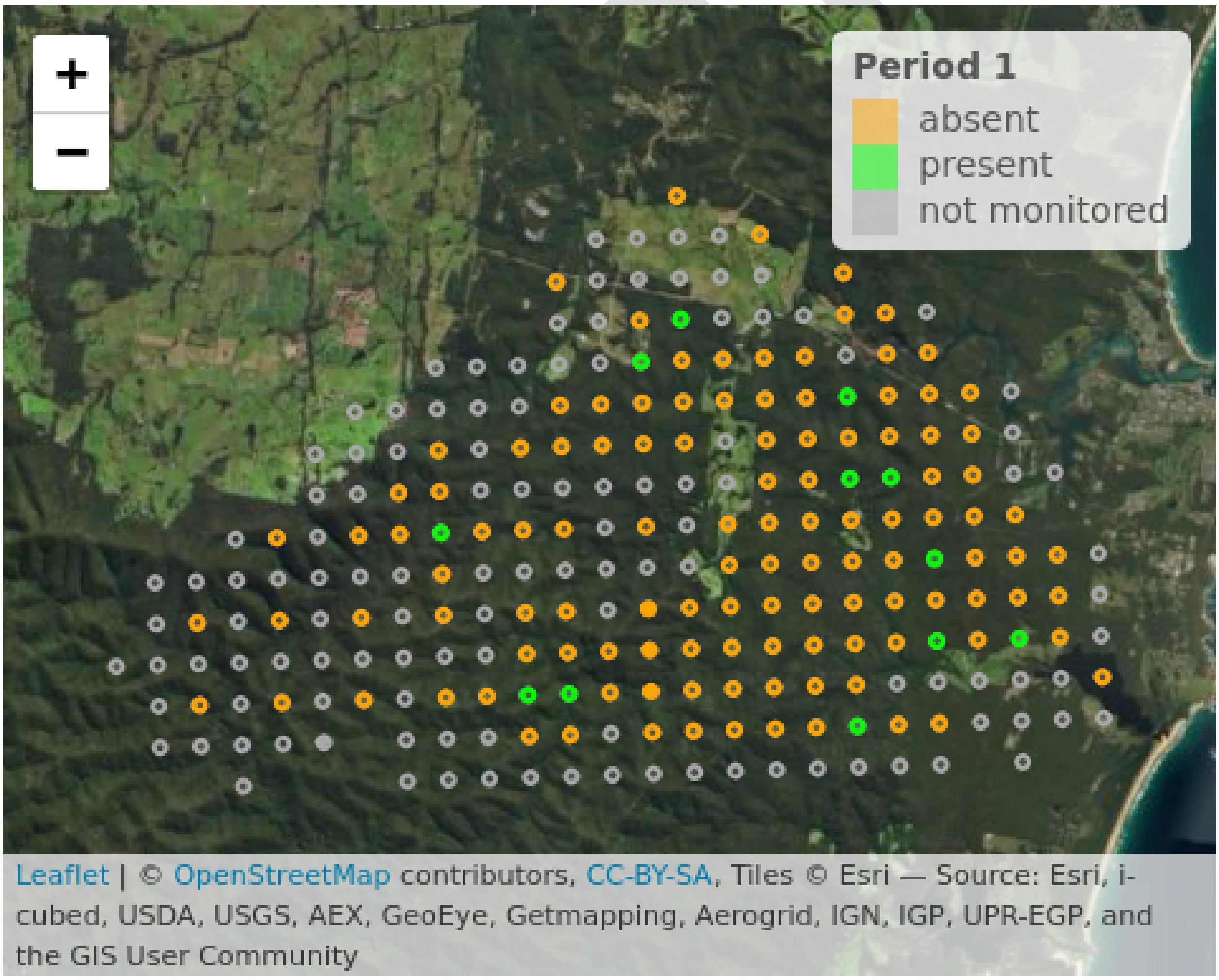
	Period 1	Period 2	Period 3
absent	116	169	59
present	12	15	9
not monitored	118	62	178
Sum	246	246	246

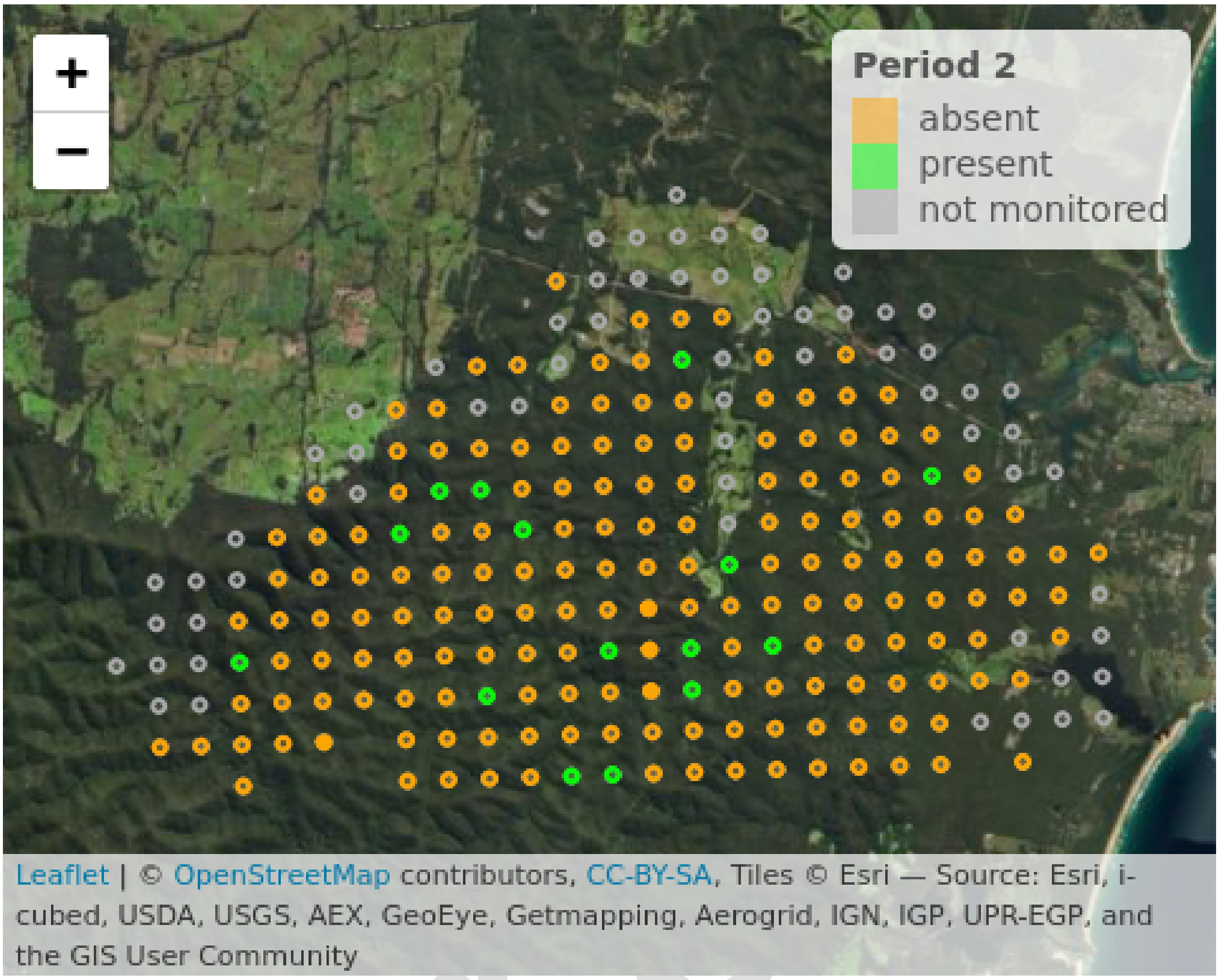
Table 4: *Percentage of occurrences of koalas per study period*

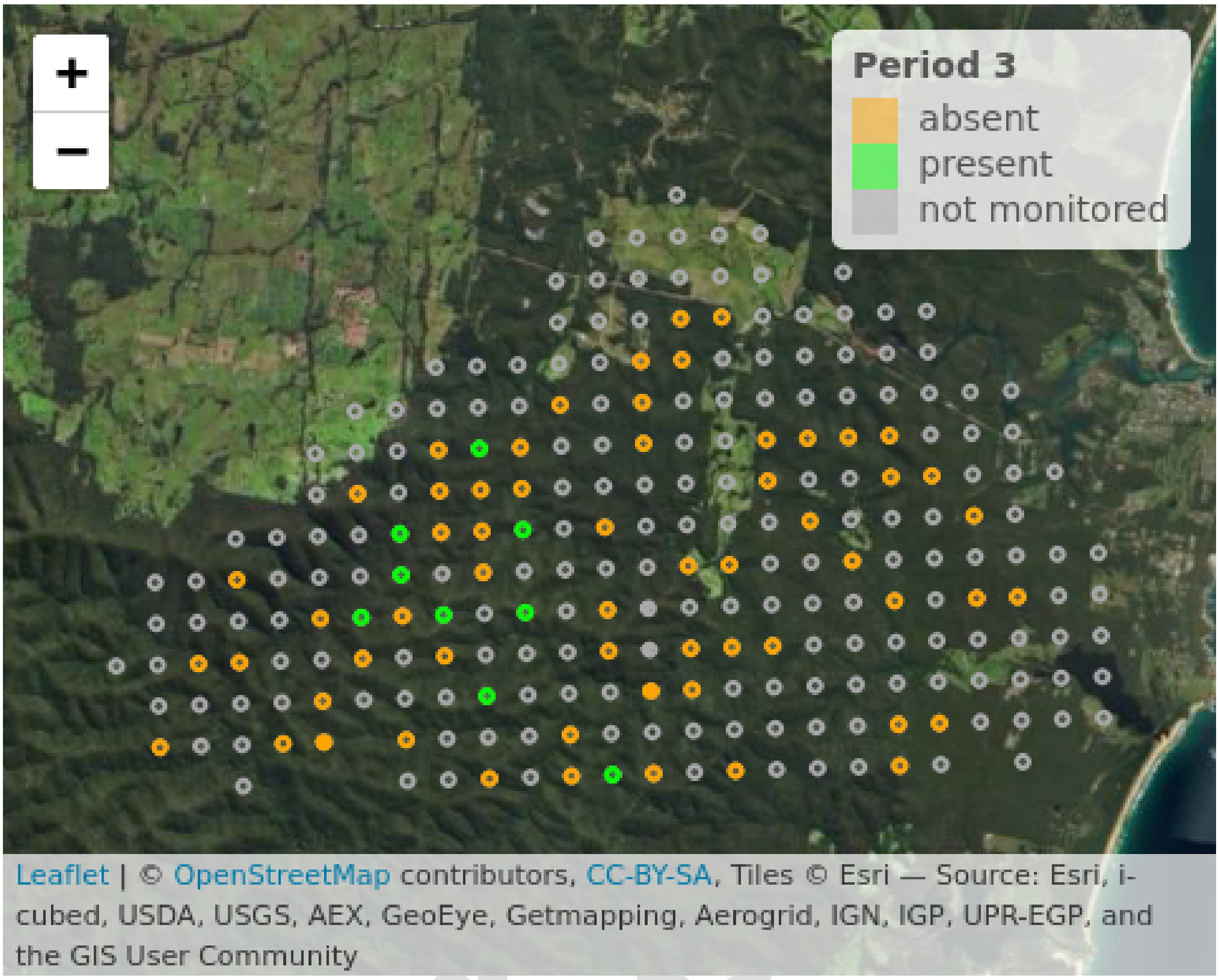
	Period 1	Period 2	Period 3
absent [%]	91	92	87
present [%]	9	8	13
Sum	100	100	100

Mapped results per period

The following figures show the grid-sites that were assessed in each monitoring period and their absence/presence results.




+
−
Period 2
absent
present
not monitored
Leaflet | © OpenStreetMap contributors, CC-BY-SA, Tiles © Esri — Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community



Estimated occupancy over time and probability of detection

A Bayesian-based occupancy modelling approach was used to estimate site occupancy. Site occupancy is analagous to to the proportion/percentage of sites that are active, but accounts for imperfect detection of koala activity. Two parameters are estimated using this approach. The first is *psi*, the proportion of sites that are occupied adjusted for imperfect detection and *p*, the probability of detection given that koala faecal pellets are present. To obtain our estimate of *p*, we treat each actual site visit as three repeated visits with 10 trees being searched as a part of each repeated visit. This step is required as the estimation of *p* requires temporally repeated visits to the same sight with the assumption that there is no change in population size or activity levels between visits. We have performed testing with varying numbers of trees being visited during the repeat visits and have found that it has only limited effects on the estimate of *p*

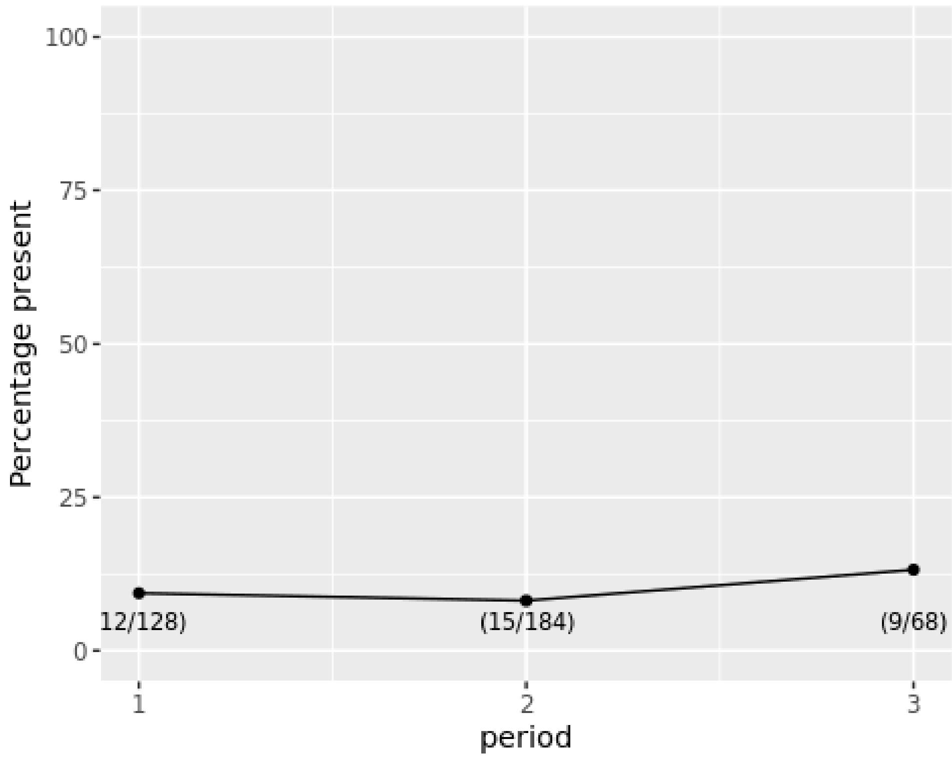


Figure 3: *Percentage of occupied sites over periods*

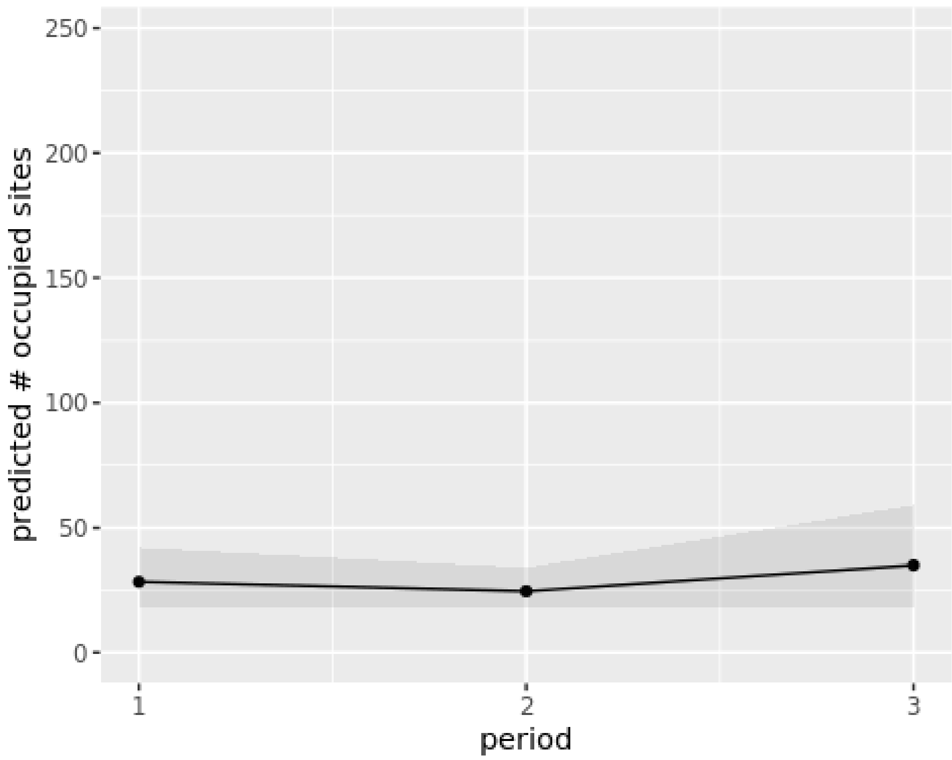


Figure 4: *Predicted number of sites occupied over periods (out of a total of 246 sites)*

Summary output of occupancy model

Table 5 below consists of the following parameters:

- the occupancy rate at each period
- the numober of occupied/active sites in each period
- the probability that koala pellets would be detected if they were present at a grid-site
- the probability that a grid-site unoccupied in a period and is occupied in the following period (site colonisation rate)
- the probability that a grid-site occupied in a period would be unoccupied in the following period (site extinction rate).

In regards to the last two columns: 2.5% indicates the measure in which the mean of the parameter will be less than the 2.5% figure 2.5% of the time in a random selection of sites, and 97.5% indicates the mean of the parameter will be less than the 97.5% figure 97.5% of the time in a random selection of sites.

Table 5: *Summary output of occupancy model.*

	mean	sd	2.5%	97.5%
occupancy rate[P1]	0.118	0.032	0.064	0.187
occupancy rate[P2]	0.107	0.026	0.063	0.163
occupancy rate[P3]	0.148	0.048	0.071	0.257
# occupied sites[P1]	28	6	18	42
# occupied sites[P2]	25	4	18	34
# occupied sites[P3]	35	11	18	59
detection probability at a site (30 trees)	0.856	0.052	0.741	0.939
colonisation rate[P1-2]	0.111	0.029	0.063	0.175
colonisation rate[P2-3]	0.125	0.051	0.043	0.243
extinction rate[P1-2]	0.073	0.068	0.002	0.254
extinction rate[P2-3]	0.34	0.126	0.124	0.613
probability of increase[P1-2]	0.393	0.489	0	1
probability of increase[P2-3]	0.79	0.407	0	1

Appendix 3: *Ikoala* tree species preference analyses

Methods

Tree species strike rates

The strike rate for each tree species was calculated by pooling the data from the 1km-interval grid-sites and calculating the proportion of trees under which koala pellets were found. The more commonly occurring and more frequently used species were also separated into two data sets, one for those on sedimentary geologies and the other for those on volcanic geologies. Stratification of sites by geologies was derived field-site data records and confirmed by soil landscape mapping (DLWC 2004a; 2004b).

Overall strike-rates

Another measure of strike rates, which was called the overall strike-rate, was developed by AEI23. The overall strike rate differs from the strike rate defined above in that data from all sites were included, regardless of koala activity.

Biolink Ecological Consultants Comprehensive Koala Plan of Management for Eastern Portion of Kempsey Shire LGA Volume II – Resource Study July 2009. Biolink Ecological Consultants Pty Ltd PO Box 196 Uki NSW 2484.

Biolink Ecological Consultants Tweed Coast Koala Habitat Study. Report to Tweed Shire Council January 2011. Biolink Ecological Consultants Pty Ltd PO Box 196 Uki NSW 2484.

Bernd Gruber, Veronika Vyˇsn´a and Aaron Adamack. Southern Tablelands Koala Survey 2012-2013. Analysis of occurrence, activity and tree preference – Report to Office of Environment and Heritage. 2014. University of Canberra ACT.

Ibid

Bernd Gruber et al. Southern Tablelands Koala Survey 2012-2013. Analysis of occurrence, activity and tree preference.

Bootstrap simulation

A bootstrap simulation with 100,000 permutations for each tree species was also performed. For each set of simulations, the relative abundance of a tree species across all visited sites was determined, the total number of trees with koala faecal pellets present, and the number of trees of the species of interest with faecal pellets present.

For each bootstrap permutation, a random deviate from a binomial distribution, which represented the number of strikes assuming koalas choose trees at random, was generated. The number of trials was set to the total number of trees with koala faecal pellets present (all tree species), and the probability of a success was set to the proportion of all trees that were trees of species X.

The random deviate was then converted to simulated strike rate by dividing the random deviate by the total number of trees of the species of interest. Finally, the difference between the observed overall strike rate and the simulated strike rate was determined. After 100,000 permutations were performed, the middle 95% of the distribution of the differences between the observed and simulated strike rates was determined. If the middle 95% of the distribution of differences for a tree species did not include 0, it indicated that koalas were actively avoiding (distribution is below 0) or selecting for (distribution is above 0) a particular tree species.

Some tree species were on the cusp of being positively or negatively selected with their selection status varying from one set of bootstrap simulations to another. By using a high number of replicates, the likelihood of that happening was reduced.

Non-metric multidimensional scaling

A non-metric multidimensional scaling to visualise the difference in terms of tree species between composition of active and inactive sites using a distance matrix (Bray-Curtis as a distance measure) between all pairs of sites was also computed was also undertaken.

Boosted regression tree allowing for non-linear responses

Habitat parameters in a boosted regression tree allowing for non-linear responses were tested and zero-inflated generalised linear models were also applied by the AEI26.

Trees of each individual species were divided into 100 mm DBH intervals (i.e. 100 to 199 mm, 200 to 299 mm, etc.) and the strike rate (i.e. the probability considering active sites only) for each size class for each species was determined. A weighted linear regression between strike rate and tree size was performed, with each size class weighted by the number of trees (of the species of interest) in the size class.

Results

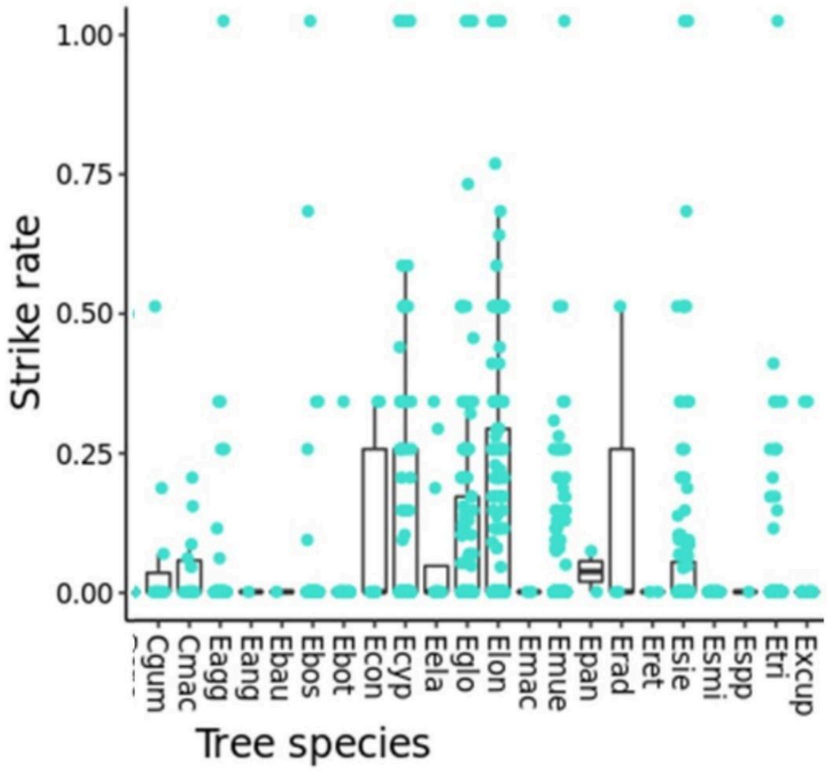
Tree species strike rates from active sites

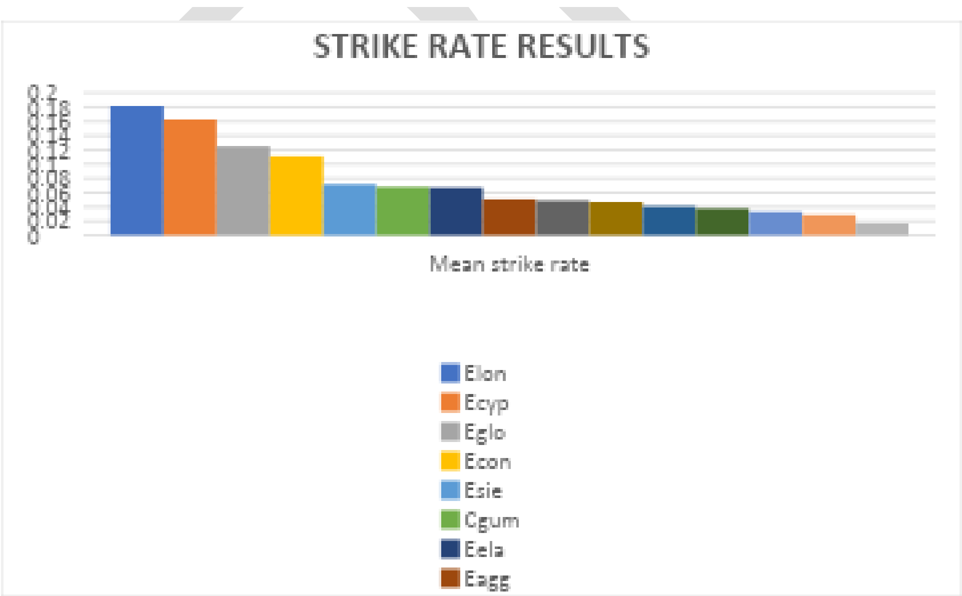
Table 5 provides the strike rate analysis results of the AEI analysis27 and includes the numbers of active and inactive sites at which each of the more common tree species occurred, the number of trees at those sites, the number of trees with pellets, the strike rates for those species and the standard error.

Table 5: Tree species strike rates, numbers of active and inactive sites at which each of the more common tree species occurred, the number of trees at active and inactive sites, the number of trees with pellets, the strike rates for those species and the standard error.

Tree ID	# of inactive sites	# of active sites	Count at inactive sites	Count at active sites	# of faecal pellets	Mean strike rate	Standard Error
Elon	841	171	4284	837	202	0.182	0.009
Ecyp	417	97	1376	356	62	0.163	0.016
Eglo	491	108	2937	747	105	0.125	0.008
Econ	68	6	258	17	4	0.111	0.042
Esie	545	123	4049	736	66	0.072	0.006
Cgum	158	11	1050	77	8	0.068	0.018
Eela	66	12	338	46	5	0.067	0.018
Eagg	313	46	1691	261	19	0.051	0.01
Ebos	329	55	1067	156	15	0.049	0.014
Emue	860	158	6659	1068	85	0.047	0.004
Etri	397	97	1071	261	33	0.041	0.008
Cmac	89	14	997	158	10	0.038	0.005
Excup	169	20	294	29	2	0.033	0.019
Alit	856	135	5886	833	39	0.029	0.004
Ebot	182	20	951	90	3	0.017	0.008

Figure 1

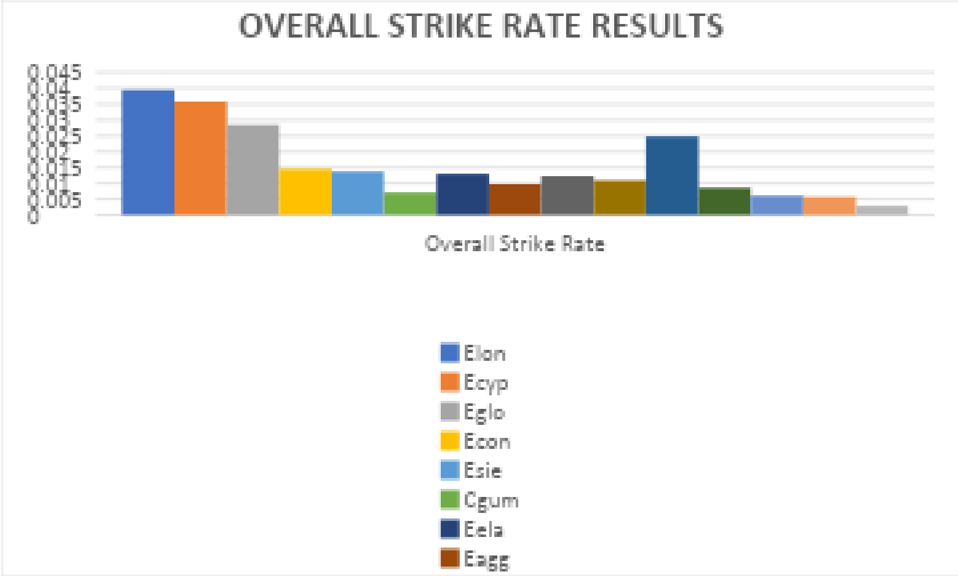




Overall strike-rates

Figure 7 below is derived from AEI28 analysis for the overall strike rates from 1km grid-sites.

Figure 7: AEI results for the overall strike rates for the pooled data from 1km grid-sites.



Bootstrap simulation

Distributions of observed - simulated strike rates assuming that koalas choose trees within the study area at random revealed that were positively selected by koalas.

OTHER BITS

Activity levels

The number of sites with 10% or more activity levels has remained consistent in both periods in Sub-area 2 but declined in Sub-Area 3. This latter measure is significant as the higher activity sites are more likely to indicate koala residency.

The consistency in regards to the number of active sites with activity levels of 10% or more in Sub-area 2 compared with the sharp drop in the number of sites with >10% activity does suggest that differences in detectability-success in the two periods may have contributed to the decline in occupancy rates as the error margin is probably higher in sites where there are only a few pellets.

What we can conclude from the results is that the increase in occupancy that we hoped for is probably not occurring, at least not in any even trajectory. Koala numbers remain low, a conclusion somewhat different from a former FNSW researcher who, basing his conclusion on a sighting of a female with young and no other evidence, stated the population *is clearly in a phase of irruption* (Jurskis 2016).

Murrah Flora Reserves

The conclusion from the monitoring results that the population remains small is important for several reasons, not least that this information was gathered at a time when much of the land sustaining the population was under State Forests NSW management and before it was transitioned to Flora Reserve status and managed by NPWS. The information from this monitoring program will make a vital contribution to management decision-making, and reviews of the effectiveness of that management.

Given the absence of fire and logging impacts in most of the study area for at least several decades now, we need to consider other factors that may be contributing to the ongoing low occupancy rates. We note the conclusion of the Chief Scientist (2016) who stated *Chlamydia is likely to continue to drive pronounced population declines in urban coastal regions in association with other mortality from habitat destruction, domestic dog attack and vehicle strike*, and acknowledge potential contribution that the episodic nature of the disease may make to occupation rate oscillations in the study area.

Predavec (2016) concluded that *low density populations are possibly more common than we once thought and that low density does not necessarily equate with a population in peril.* This is a welcome conclusion for those of us who have been working with low density populations in SENSW, though the low numbers within this population (probably between 30 and 60 animals) remains of concern.

Comparative analysis of 2007-9 and 2012-14 data

Adamack et al (2016)[35] investigated the extent the foundational datasets from this and previous surveys could contribute to a koala population monitoring program.

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[35] Aaron Adamack, Veronika Vysna & Bernd Gruber (2016). *Comparison of Koala Surveys in South-Eastern NSW Coastal Forests 2007-2009 & 2010-2013 Analysis of occurrence, activity and tree preference –Report.* University of Canberra, ACT.

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The results from analyses of koala pellets undertaken by the Koala Health Hub (USyd) does suggest that *Chlamydia* …………………………………...

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APPENDIX 2: Using the Regularised Grid-based Spot Assessment Technique as a monitoring tool

The efficacy of Regularised Grid-based Spot Assessment Technique

For the past decade the Regularised Grid-based Spot Assessment Technique **(**RGb-SAT) has been the foundational koala survey and monitoring tool in SENSW, where, in this part of the koala's range, only low-density populations occur. From the conflicting interpretations of the koala's conservation status and habitat needs that were the norm 20 years ago and the consequent impotence around management (Cork et al), the method has provided common ground for agencies and community organisations to work together improve knowledge, monitor and manage koala populations. More than 2,000 grid-sites have been assessed in five study areas (one of which is in the Strzelecki Ranges in Victoria) and the data has made a significant contribution to knowledge about koala distribution, abundance and habitat preferences.

The method has been criticised (eg Woosnam – Merchez 2013[36]) though much of this appears based on a lack of understanding of the methods, and the validated knowledge that has been gained through its application (Phillips and Callaghan 2014)[37].

To our knowledge, the method has not been used in any large-scale way to monitor populations, though it does have the potential to do so because the data derived from this method is so extensive. One of our unique contributions to the evolution of RG-bSAT therefore is such a large-scale program. This uses a grid-site selection process for systematic reassessment that improves the robustness of statistical analyses.

In addition, the *ikoala* tool being developed by University of Canberra and linked to the SENSW database will enable the automatic generation of analysis of koalas' tree species and size class preferences, distribution and occupancy rates, and changes in these rates over time.

At this stage in the program we can say the following about the utility of this monitoring method:

1. It is the only method currently available that can reliably monitor a low-density koala population that extends over many thousands of hectares.
2. It provides a basis to fulfil the observation of Predavec (2016) that *it is only through long term and repeat studies of koala populations that we start to understand the patterns of population change.*
3. It provides the opportunity to systematically gather other ecological data, including other fauna species, fuel-loads and canopy condition, from across the landscape;
4. It provides opportunities for community (including the Aboriginal community) to participate in the fieldwork and share knowledge.
5. Data is gathered electronically and uploaded into a database specifically designed for the program.
6. Analysis of the data, including the koalas' tree species and size class preferences, distribution and occupancy rates can be analysed efficiently through the application of *ikoala.*

The Chief Scientist (2016) report into the decline of koala populations in key areas in NSW emphasises the importance of developing long-term koala population monitoring programs, yet provides no clear guidelines as to how this might be undertaken. The report makes no mention of the monitoring in SENSW and to our knowledge no information was provided to the Chief Scientist about the program.

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[36] Woosnam – Merchez et al (2013)

[37]

The report recommends that: *Government initiate a program to improve data on the number, location and occurrence of koalas in NSW, including trends over time, taking advantage of new sensor and communication technologies and data analytics within 12 months of receipt of this report……. In particular, new sensor technologies and data analytics can be employed, in combination with data gathered through EIS, citizen science and traditional survey methods such as scat surveys, to build a much richer picture of koala occurrence. Data fusion techniques can bring this information together which can then be used to inform better models of population and habitat. The raw data should also be available in the SEED Environmental Data Portal (extended if necessary to include flora and fauna) for open access by government, community and researchers.*

We acknowledge the potential for a more integrated approach to monitoring and welcome opportunities to apply improved technologies and data analytics that should evolve through the implementation of this recommendation.