

The Spot Assessment Technique: a tool for determining localised levels of habitat use by Koalas *Phascolarctos cinereus*

Stephen Phillips¹ and John Callaghan²

Australian Koala Foundation

GPO Box 2659 Brisbane, Queensland 4001, Australia

¹Current Address: Biolink Ecological Consultants PO Box 3196 Uki NSW 2484 Australia.

²Current Address: Gold Coast City Council PO Box 5042 Gold Coast MC 9729 Australia.

Corresponding author: Stephen Phillips, Biolink Ecological Consultants, PO Box 3196, Uki, NSW 2484 Australia (Tel: +61 2 66795593; Fax +61 2 66795523; email steve@biolink.com.au).

ABSTRACT

In order to more effectively conserve Koalas, the National Koala Conservation and Management Strategy 2009 – 2014 promotes the need for reliable approaches to the assessment of Koala habitat. This work describes a point-based, tree sampling methodology that utilises the presence/absence of Koala faecal pellets within a prescribed search area around the base of trees to derive a measure of Koala activity. Confidence intervals associated with Koala activity data from 405 randomly selected field plots within which faecal pellets were recorded have been utilised to assign threshold values for three population density/habitat biomes in eastern Australia. Subject to the need for a precautionary approach to data interpretation in areas that support naturally occurring, low-density Koala populations, the approach is expected to assist field-based assessments by researchers, land managers and others interested in clarifying aspects of habitat utilisation by free-ranging Koalas, especially where identification of important areas for protection and management is required.

Key words: Spot Assessment Technique, Koala, *Phascolarctos cinereus*, SEPP 44.

Introduction

The primary aim of the National Koala Conservation and Management Strategy 2009 – 2014 (NKCMS) is to conserve the Koala (*Phascolarctos cinereus*) by retaining viable populations in the wild throughout the species' natural range (Natural Resource Management Ministerial Council (NRMMC) 2009). In order to assist this aim, Action 1.06 of the NKCMS promotes the need for development of standard monitoring/habitat assessment protocols as a means of addressing the issue of inconsistency and disagreement over how koala populations should be surveyed and mapped (NRMMC 2009).

The primary responsibility for conservation of free-ranging *P. cinereus* populations rests with State, Territory and Local Government authorities. In this regard State Government authorities in New South Wales and Queensland have enacted specific planning policies and/or strategic planning measures to assist *P. cinereus* conservation efforts. However, the ability of such approaches to achieve their stated conservation objectives is impeded in part by the lack of standardised and reproducible methods that can be applied to the task of *P. cinereus* habitat/population assessment in the first instance.

In this paper we present a technique that we believe contributes to the need for a reliable approach to objectively assessing aspects of habitat use by *P. cinereus*. An unreviewed progenitor to this work (Phillips and Callaghan 1995) was originally circulated to a limited audience following the Australian Koala Foundation's

1995 conference on the status of Koalas, its purpose at that time to promulgate an approach that could potentially assist field-based assessments by ecological consultants, land managers and others interested in quantifying aspects of habitat utilisation by free-ranging *P. cinereus*. The purpose of this paper is to further refine the initial approach in the light of feedback and additional field studies and in so doing, formally supersede the earlier work.

Background to the approach

Traditionally, knowledge relating to habitat utilisation by free-ranging *P. cinereus* has been primarily reliant on opportunistic observations or radio-tracking data (Robbins and Russell 1978; Martin 1985; Hindell *et al.* 1985; Hindell and Lee 1987; 1988; White and Kunst 1990; Reed *et al.* 1990; Hasegawa 1995; Melzer and Lamb 1996; Pieters and Woodhall 1996). In other instances, emphasis has been placed on benign indicators such as accumulated faecal pellet counts (Moon 1990; Munks *et al.* 1996; Pahl 1996) and scratch marks. However, all of these approaches can be problematic. Firstly, existing models for determining tree preferences by free-ranging *P. cinereus* (Hindell *et al.* 1985) require a number of assumptions to be met which do not appear to hold in heterogeneous forest communities (Phillips 1999; Ellis *et al.* 2002). Secondly, while careful analysis of accumulated faecal pellet counts can elucidate issues of *P. cinereus* abundance (Sullivan *et al.* 2002, 2004), such

counts have proved to be of limited value when used to infer the importance of various tree species (Munks *et al.* 1996; Pahl 1996). The ability to census and interpret faecal pellet deposits can also be influenced by other variables including visibility, tree morphometrics and insect activity (Achurch 1989; Jones 1994; Melzer *et al.* 1994; Pahl 1996; Ellis *et al.* 1998; Sullivan *et al.* 2003). Scratch marks on trees are also an unreliable indicator of habitat use – they cannot be detected on some species whereas others retain them for long periods of time - nor is it always possible to confidently distinguish scratches made by *P. cinereus* from those of other arboreal animals.

Studies of free-ranging *P. cinereus* populations have established that those in stable breeding aggregations arrange themselves in a matrix of overlapping home range areas (Lee and Martin 1988; Faulks 1990; Mitchell 1990). Home range areas vary in size depending upon the quality of the habitat (measurable in terms of the density of preferentially utilised food tree species) and the sex of the animal (males tend to have larger home range areas than females). Long-term fidelity to the home range area is generally maintained by adult *P. cinereus* in a stable population (Mitchell 1990; Phillips 1999, Kavanagh *et al.* 2007). An additional feature of *P. cinereus* home range use is the repeated use of certain trees, some of which may also be utilised by other members of the population (Faulks 1990; Mitchell 1990; Phillips 1999; Ellis *et al.* 2002).

Given the preceding considerations, it follows that areas being utilised by socially stable/resident *P. cinereus* populations must also be characterised by a higher rate of faecal pellet deposition (see Lunney *et al.* 1998). For the purposes of this paper, we propose the term “areas of major activity” to describe such localities, regarding them as synonymous with the term “Core Koala Habitat” (in so far as this term relates to the presence of a “resident population of koalas”) as defined by the NSW Government’s *State Environmental Planning Policy No. 44 (Koala Habitat Protection)*, as well as being a fundamental element of “Koala Habitat Areas” as defined by the *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006 – 2016* (Environment Protection Agency/Queensland National Parks and Wildlife Service 2006).

The Spot Assessment Technique

The Spot Assessment Technique (SAT) is a truncated form of the methodology originally developed by the Australian Koala Foundation for purposes of the Koala Habitat Atlas project (Sharp and Phillips 1997; Phillips *et al.* 2000; Phillips and Callaghan 2000). The Atlas approach is probability-based and utilises a binary variable (presence/absence of faecal pellets within a prescribed search area around the base of trees) to determine tree species preferences, along with a commensurate measure of *P. cinereus* “activity” (number of trees with faecal pellets divided by total number of trees in the plot) within a 40m x 40m

(1600m²) plot. Given that the selection of Atlas field plots is primarily based on stratification and replication using soil landscape and vegetation association data in the first instance, the data presented for the purposes of this paper reflects a random selection of field sites within which *P. cinereus* faecal pellets were recorded. The SAT approach arose from observations of consistency within the four smaller (20m x 20m) sub-quadrats that otherwise comprise Atlas field plots and the consequent realisation that a smaller plot size essentially provided the same empirical outcomes in terms of both tree species/faecal pellet associations and activity *per se*. However, the number of trees sampled in a smaller site is critical in terms of ascribing meaningful variance to the activity estimate hence we have adopted this measure as the more important variable for the purposes of the technique. Thus, in order to establish a meaningful confidence interval for the activity level of a given SAT site, a minimum of thirty (30) trees must be sampled. For assessment purposes, a tree is defined as “a live woody stem of any plant species (excepting palms, cycads, tree ferns and grass trees) which has a diameter at breast height (dbh) of 100 mm or greater” (Phillips *et al.* 2000); in the case of multi-stemmed trees, at least one of the live stems must have a dbh of 100 millimetres or greater in order to qualify.

Table 1 provides a data summary from Atlas field plots undertaken across a variety of habitat types and landscapes utilised by *P. cinereus* in eastern Australia. To this end, while we consider significant differences between mean activity levels from low and medium - high density *P. cinereus* populations of the eastern seaboard to reflect real differences in habitat carrying capacity (Table 1 - Southeast Forests/Campbelltown vs Port Stephens/Noosa: Levene’s test: $F = 0.086$, $P > 0.05$; $t = -7.877$, $P < 0.001$), we speculate that similar differences between medium - high density populations of the eastern seaboard and those from more western areas (areas generally receiving less than 600mm of rainfall annually) (Port Stephens/Noosa vs Pilliga/Walgett – Levene’s test: $F = 0.925$, $P > 0.05$; $t = -4.743$, $P < 0.001$) more likely reflect differences in faecal pellet longevity as a consequence of aridity than they do habitat quality *per se*. This said, we acknowledge that there are also likely to be both low and medium-high density populations in western areas of the species’ range, the differentiation of which will require further investigation and evaluation.

Applying the SAT

The SAT involves a radial assessment of *P. cinereus* “activity” within the immediate area surrounding a tree of any species that is known to have been utilised by the species, or otherwise considered to be of some importance for *P. cinereus* conservation and/or management purposes. In the field the technique is applied as follows:

1. Locate and uniquely mark with flagging tape a tree (the centre tree) that meets one or more of the following selection criteria:

Table 1. Mean activity levels and related measures of central tendency (expressed as percentage equivalents) associated with habitat utilisation by Koalas from six areas in eastern Australia. Data relates to sites within which faecal pellets were recorded and has been pooled to reflect three major categories of activity which correspond to naturally occurring low and med-high density populations of the tablelands and areas east of the Great Dividing Range, and those of more western areas respectively. Koala densities for the east coast, low density category are arbitrarily defined at ≤ 0.1 Koalas/ha. (Data sources: ¹South-east Forests Conservation Council, unpub. data; ²Phillips and Callaghan 1997; ³Phillips and Callaghan 2000; ⁴Phillips *et al.* 1996; ⁵Phillips *et al.* 2000; ⁶AKF, unpub.data; ⁷Phillips 1999; ^{8,9}AKF unpub. data).

Area	Pop. Density	No. sites	No. trees	A/level	SD	SE	99% CL
East Coast							
S/E Forests ¹	Low	111	2979	11.85	6.84	0.65	1.70
Campbelltown ^{2,3}	Low	20	1194	6.52	4.72	1.06	3.02
Pooled		131	4173	11.03	6.82	0.60	1.56
East Coast							
Port Stephens ^{4,5}	Med - high	76	3847	23.65	23.63	2.71	7.16
Noosa ⁶	Med - high	63	1647	32.55	22.05	2.78	7.38
Pooled		139	5494	27.68	23.27	1.97	5.16
Western Slopes & Plains							
Pilliga ^{7,8}	Med - high	98	3656	42.52	22.78	2.30	6.05
Walgett ⁹	Med - high	37	990	38.01	27.66	4.55	12.37
Pooled		135	4646	41.28	24.19	2.08	5.44

- a tree of any species beneath which one or more *P. cinereus* faecal pellets have been observed and/or
- a tree in which a *P. cinereus* has been observed and/or
- any other tree known or considered to be potentially important for *P. cinereus*, or of interest for other assessment purposes.

- identify and uniquely mark the 29 nearest trees to the centre tree,
- undertake a search for *P. cinereus* faecal pellets beneath each of the 30 marked trees based on a cursory inspection of the undisturbed ground surface within a distance of 100 centimetres around the base of each tree, followed (if no faecal pellets are initially detected) by a more thorough inspection involving disturbance of the leaf litter and ground cover within the prescribed search area.

Strict adherence to the 100 cm search area is a fundamental component of the SAT methodology. As detailed in Appendix 1, it is this distance that both optimises the probability of success in terms of actually finding faecal pellets, while at the same defining a workable search area. Any lesser search area and the probability of success will be significantly reduced (Figure 2 in Appendix 1 refers) such that the mean activity levels and associated activity level thresholds applicable to the approach cannot be justifiably applied.

In terms of search effort, an average of approximately two person minutes per tree should be dedicated to the faecal pellet search. In practice, more time will be spent searching beneath larger trees than smaller trees. For assessment purposes, the search should be concluded once a single faecal pellet has been detected or when the maximum search time has expired, whichever happens first. This process should be repeated until each of the 30 trees in the site has been assessed. Where the location of faecal pellets falls within overlapping search areas

due to two or more trees growing in close proximity to each other, both should be scored for pellet(s). For more detailed reporting purposes, information relating to the site's location (UTM co-ordinates or Lat/Long), selection criteria, tree species assessed (and dbh), and the radial area searched (as measured by distance from the centre tree) should also be recorded. Faecal pellets should not be removed from the site unless some verification (i.e. that they are in fact *P. cinereus* faecal pellets) is necessary.

Calculation and interpretation of Koala activity levels

The activity level for a SAT site is simply expressed as the percentage equivalent of the proportion of surveyed trees within the site that had a *P. cinereus* faecal pellet recorded within the prescribed search area. For example, given a sample of 30 trees, 12 of which had one or more faecal pellets recorded – the resulting activity level would be determined as $12/30 = 0.4 = 40$ per cent.

From the data sets presented in Table 1, we opted for a precautionary approach by proposing use of mean activity levels ± 99 per cent confidence intervals to define the limits of “normal” *P. cinereus* activity. Based on the threshold values that result, three categories of activity – “low”, “medium(normal)” and “high” can thus be determined for each of the three area/population density categories detailed in Table 2. Subject to qualifications regarding the need for a cautious approach to low activity levels in some instances (see below), where the results of a SAT site returns an activity level within the low use range, the level of use by *P. cinereus* is likely to be transitory. Conversely, where a given SAT site returns an activity level within the prescribed range for medium (normal) to high use - the level of use is indicative of more sedentary ranging patterns and is thus within an area of major activity.

Table 2. Categorisation of Koala activity into Low, Medium (normal) and High use categories based on use of mean activity level \pm 99 per cent confidence intervals (nearest percentage equivalents) from each of the three area/population density categories indicated in Table 1.

Activity category	Low use	Medium (normal) use	High use
Area (density)			
East Coast (low)	-	$\geq 3.33\%$ but $\leq 12.59\%$	$> 12.59\%$
East Coast (med – high)	$< 22.52\%$	$\geq 22.52\%$ but $\leq 32.84\%$	$> 32.84\%$
Western Plains (med – high)	$< 35.84\%$	$\geq 35.84\%$ but $\leq 46.72\%$	$> 46.72\%$

A precautionary approach to activity levels in low use areas.

Ideally, SAT site activity levels should only be interpreted in the context of location-specific habitat utilisation data (e.g. Lunney *et al.* 1998; Phillips *et al.* 2000; Phillips and Callaghan 2000; Phillips and Hopkins 2009). Low activity levels recorded in what might otherwise be med-high carrying capacity *P. cinereus* habitat may be a result of contemporary population dynamics, landscape configuration and/or historical disturbances including logging, mining, fire, agricultural activities and/or urban development. Such considerations should not necessarily detract from the potential importance of such habitat for longer-term conservation, particularly if preferred koala food trees are present and populations of *P. cinereus* are known to occur in the general area. Ideally, any determination of the importance of activity levels in such instances should be informed by a broader, soil-based understanding of tree preferences (e.g. Phillips and Hopkins 2009), and in conjunction with an understanding of ecological history (e.g. Knott *et al.* 1998; Seabrook *et al.* 2003).

Low activity levels are also associated with low-density *P. cinereus* populations. Stable, low-density *P. cinereus* populations occur naturally in some areas (Melzer and Lamb 1994; Jurskis and Potter 1997; Phillips and Callaghan 2000; Ellis *et al.* 2002; Sullivan *et al.* 2006). The density of *P. cinereus* in such areas generally reflects the absence of “primary” food tree species and reliance by the population on “secondary” food tree species only (Phillips and Callaghan 2000; Phillips 2000). While secondary food tree species will return significantly higher levels of utilisation when compared to other *Eucalyptus* spp. in the area, their level of use (as determined by field survey) will

invariably be both size-class and/or density dependent when compared to a primary food tree species (Phillips and Callaghan 2000; Phillips 2000; Moore and Foley 2005). Because the autecology of *P. cinereus* occupying habitat areas that do not naturally support one or more “primary” food tree species remains poorly understood at this point in time, again we advocate a precautionary approach whereby the presence of any activity in areas occupied by naturally occurring, low density populations should be regarded as ecologically meaningful for conservation and management purposes until proven otherwise.

Concluding comment

The SAT is intended for application in conjunction with land-use planning activities that require *P. cinereus* habitat to be assessed, especially where identification of important areas for protection and management is required. The technique is suitable for use in conjunction with stratified/random or systematic survey techniques but has proved especially powerful when applied at the landscape-scale using a regularised grid-based sampling design and appropriate spatial modelling techniques (see Phillips *et al.* 2007; Phillips and Hopkins 2007; Phillips and Hopkins 2009; Allen *et al.* 2010; Phillips *et al.* submitted); it is also suitable for long-term monitoring purposes. Further information and advice regarding application and use of the technique and its application to the tasks of koala management can be supplied if required.

In refining the SAT approach over the intervening time period since its initial inception and development, we have deliberately opted for efficiency (in terms of time) and reproducibility in the field, all the while mindful that it must remain a robust sampling tool capable of answering the critical questions associated with koala conservation biology.

Acknowledgments

We are indebted to the many individuals and organisations that have generously given their time, energy and support to Koala Habitat Atlas field projects over the years. The work of Maria Jones also played a pivotal role in development of the SAT approach, for

which we thank her most graciously. We also appreciate the constructive criticism provided by colleagues who have reviewed various drafts of this paper, and others who use the technique; this revision has benefited greatly as a result.

References

- Achurch, H.M. 1989. *Tree utilisation by Koala (Phascolarctos cinereus) populations with regard to their geographic distribution within close proximity to the city of Brisbane.* Honours Thesis, University of Queensland, St Lucia.
- Allen, C., Saxon, M. and McDougall, K. 2010. *Summary report on surveys conducted in 2007-2009 for Koalas in the coastal forests of the Bermagui/Mumbulla area.* NSW Department of Environment, Climate Change and Water.

- Ellis, W.A.H., Sullivan, B.J., Lisle, A.T. and Carrick, E.N. 1998. The spatial and temporal distribution of Koala faecal pellets. *Wildlife Research* 25: 663–68.
- Ellis, W. A. H., Melzer, A., Carrick, E. N. and Hasegawa, M. 2002. Tree use, diet and home range of the koala (*Phascolarctos cinereus*) at Blair Athol, central Queensland. *Wildlife Research* 29: 303 – 11.
- Environment Protection Agency/Queensland National Parks and Wildlife Service. 2006. Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006 – 2016. Queensland Government – Environment Protection Agency.
- Faulks, J. 1990. *The Ranging Behaviour of Koalas*. Honours Thesis, Southern Cross University (formerly University of New England, Northern Rivers), Lismore, NSW, Australia.
- Hasegawa, M. 1995. *Habitat Utilisation by Koalas (Phascolarctos cinereus) at Point Halloran, Queensland*. Masters Thesis, University of Queensland, Australia.
- Hindell, M.A., Handasyde, K.A. and Lee, A.K. 1985. Tree species selection by free-ranging Koala populations in Victoria. *Australian Wildlife Research* 12: 137–44.
- Hindell, M.A. and Lee, A.K. 1987. Habitat use and tree preferences of Koalas in a mixed eucalypt forest. *Australian Wildlife Research* 14: 349–60.
- Hindell, M.A. and Lee, A.K. 1988. Tree use by individual Koalas in a natural forest. *Australian Wildlife Research* 15: 1–7.
- Jones, M. 1994. The use of scats to assess koala habitats in northern New South Wales. Unpub. 3rd year Integrated Project, School of Resource Science and Management, Southern Cross University, Lismore, New South Wales.
- Jurskis, V. and Potter, M. 1997. Koala Surveys, Ecology and Conservation at Eden. *Research Paper No. 34*. State Forests of New South Wales, Australia.
- Knott, T., Lunney, D., Coburn, D. and Callaghan, J. 1998. An ecological history of Koala habitat in Port Stephens Shire and the Lower Hunter on the Central Coast of New South Wales, 1801 – 1998. *Pacific Conservation Biology* 4: 354–68.
- Lee, A. and Martin, R. 1988. *The Koala – A Natural History*. NSW University Press, Sydney, Australia.
- Lunney, D., Phillips, S., Callaghan, J. and Coburn, D. 1998. A new approach to determining the distribution of Koalas and conserving their habitat: a case study from Port Stephens Shire on the central coast of New South Wales. *Pacific Conservation Biology* 4: 186–96.
- Martin, R.W. 1985. Overbrowsing, and Decline of a Population of the Koala, *Phascolarctos cinereus*, in Victoria I. Food Preference and Food Tree Defoliation. *Australian Wildlife Research* 12: 355–65.
- Melzer, A., Schneider, M. A. and Lamb, D. 1994. Insects associated with the faecal pellets of the Koala, *Phascolarctos cinereus* Goldfuss. *Australian Entomologist* 21 (3): 69 – 70.
- Melzer, A. and Lamb, D. 1994. Low density populations of the Koala (*Phascolarctos cinereus*) in Central Queensland. *Proceedings of the Royal Society of Queensland* 104: 89–93.
- Melzer, A. and Lamb, D. 1996. Habitat utilisation by a central Queensland Koala colony. Pp 17–26 in *Koalas – Research for Management* 17–26, edited by G. Gordon. World Koala Research Incorporated, Brisbane, Australia.
- Mitchell, P. 1990. The home ranges and social activity of Koalas - a quantitative analysis. Pp 177–87 in *Biology of the Koala*, edited by A.K. Lee, K.A. Handasyde and G.D. Sanson. Surrey Beatty and Sons, Sydney, Australia.
- Moon, C. 1990. Koala corridors: A case study from Lismore. Pp. 87–92 in *Koala Summit – Managing Koalas in New South Wales*, edited by D. Lunney, C.A. Urquhart and P. Reed. NSW National Parks and Wildlife Service, Sydney, Australia.
- Moore, B. D. and Foley, W. J. 2005. Tree use by koalas in a chemically complex landscape. *Nature* 435: 488 – 90.
- Munks, S. A., Corkrey, R. and Foley, W.J. 1996. Characteristics of arboreal marsupial habitat in the semi-arid woodlands of northern Queensland. *Wildlife Research* 23: 185–95.
- Natural Resource Management Ministerial Council. 2009. *National Koala Conservation and Management Strategy 2009 - 2014*. Department of the Environment Environment, Water, Heritage and the Arts. Canberra.
- Pahl, L. 1996. Koala and bushland survey of west and central Logan City. Pp. 82–92 in *Koalas - research for management*, edited by G. Gordon. World Koala Research Incorporated, Brisbane, Australia.
- Phillips, S. S. 1999. *Habitat utilisation by the Koala (Phascolarctos cinereus) – towards a new approach for effective conservation and management*. PhD Thesis, School of Resource Science and Management, Southern Cross University, Lismore, Australia.
- Phillips, S. S. 2000. *Tree species preferences of the Koala Phascolarctos cinereus as a basis for the delineation of management areas for recovery planning in New South Wales*. Report prepared for NSW Koala Recovery Plan.
- Phillips, S. and Callaghan, J. 1995. The Spot Assessment Technique for determining the significance of habitat utilisation by Koalas. Addendum to *Proceedings of a conference on the status of the Koala in 1995*. Australian Koala Foundation, Brisbane, Australia.
- Phillips, S., Callaghan, J. and Thompson, V. 1996. *The Koala Habitat Atlas - Project No. 6: Port Stephens Local Government Area*. Australian Koala Foundation, Brisbane, Australia.
- Phillips, S. and Callaghan, J. 1997. *Koala Habitat Atlas, Project No. 5: Campbelltown Local Government Area*. Australian Koala Foundation: Brisbane.
- Phillips, S., Callaghan, J. and Thompson, V. 2000. The tree species preferences of Koalas (*Phascolarctos cinereus*) inhabiting forest and woodland communities on Quaternary deposits in the Port Stephens area, New South Wales. *Wildlife Research* 27: 1–10.
- Phillips, S. and Callaghan, J. 2000. Tree species preferences of a Koala (*Phascolarctos cinereus*) population in the Campbelltown area south-west of Sydney, New South Wales. *Wildlife Research* 27: 569–75.
- Phillips, S., Hopkins, M. and Callaghan, J. 2007. *Koala Habitat and Population Assessment for the Gold Coast City Local Government Area*. Final Report to Gold Coast City Council. Biolink Ecological Consultants.
- Phillips, S. and Hopkins, M. 2007. *The utility of regularised, grid based sampling for the purposes of identifying areas being utilised by koalas (Phascolarctos cinereus) in the South-east forests of NSW – a Pilot Study*. Report to NSW Department of Environment and Climate Change. Biolink Ecological Consultants.
- Phillips, S. and Hopkins, M. 2009. *Comprehensive Koala Plan of Management for eastern portion of Kempsey Shire Local Government Area, Vol II – Resource Study*. Prepared for Kempsey Shire Council. Biolink Ecological Consultants.
- Phillips, S., Hopkins, M. and Warnken, J. Submitted. *Splines in the sand: modelling metapopulation structure across heterogeneous landscapes to provide greater planning certainty for an arboreal marsupial (Koala Phascolarctos cinereus Goldfuss). Landscape and Urban Planning*.

- Pieters, C.W. and Woodhall, P.F. 1996. Daily movement patterns and habitat utilisation of Koalas (*Phascolarctos cinereus*) exposed to different levels of habitat modification. Pp. 23–28 in *Koalas - research for management*, edited by G. Gordon. World Koala Research Incorporated, Brisbane, Australia.
- Reed, P.C., Lunney, D. and Walker, P. 1990. A 1986–1987 survey of the Koala *Phascolarctos cinereus* (Goldfuss) in New South Wales and an ecological interpretation of its distribution. Pp. 55–74 in *Biology of the Koala*, edited by A.K. Lee, K.A. Handasyde and G.D. Sanson. Surrey Beatty and Sons, Sydney, Australia.
- Robbins, M. and Russell, E. 1978. Observations on Movement and Feeding Activity of the Koala in a Semi-natural Situation. Pp. 29–41 in *The Koala – Proceedings of the Taronga Symposium*, edited by T. Bergin. Zoological Parks Board of NSW, Sydney, Australia.
- Seabrook, L. M., McAlpine, C. A., Phinn, S. R., Callaghan, J. and Mitchell, D. 2003. Landscape legacies: Koala habitat change in Noosa Shire, South-east Queensland. *Australian Zoologist* 32: 446–61.
- Sharp, A. and Phillips, S. 1997. Koalas, Science and Conservation. Pp. 290–01 in *Saving Our Natural Heritage – The Role of Science in Managing Australia's Ecosystems*, edited by C. Copeland and D. Lewis. Halstead Press, Sydney, Australia.
- Sullivan, B. J., Baxter, G. S. and Lisle, A. T. 2002. Low-density Koala (*Phascolarctos cinereus*) populations in the mulgalands of south-west Queensland. I. Faecal pellet sampling method. *Wildlife Research* 29: 455 – 62.
- Sullivan, B. J., Baxter, G. S. and Lisle, A. T. 2003. Low-density Koala (*Phascolarctos cinereus*) populations in the mulgalands of south-west Queensland. III. Broad-scale patterns of habitat use. *Wildlife Research* 30: 583 – 91.
- Sullivan, B. J., Baxter, G. S., Lisle, A. T., Pahl, L. and Norris, W. M. 2004. Low-density Koala (*Phascolarctos cinereus*) populations in the mulgalands of south-west Queensland. IV. Abundance and conservation status. *Wildlife Research* 31: 19 – 29.
- White, N.A. and Kunst, N.D. 1990. Aspects of the ecology of the Koala in southeastern Queensland. Pp. 109–16 in *Biology of the Koala*, edited by A.K. Lee, K.A. Handasyde and G.D. Sanson. Surrey Beatty and Sons, Sydney, Australia.

APPENDIX Some probabilistic aspects of the SAT approach

Over the years many individuals have contributed to development and refinement of the Koala Habitat Atlas methodology and its derivative progeny the Spot Assessment Technique.

In 1994, Southern Cross University student Maria Jones was set the task of examining the distribution of *P. cinereus* faecal pellets beneath trees used by the species. Thirty spatially independent Forest Red Gums *Eucalyptus tereticornis* were selected for assessment, each of which was confirmed to have been used by *P. cinereus* on the basis of one or more faecal pellets being observed beneath their respective canopies. Forest Red Gum was selected because it was known to be a preferred food tree throughout the range of *P. cinereus* in eastern Australia. Beneath each of these trees both the number and distribution of faecal pellets were recorded at 200 mm radial increments from the base, along with other data such as tree dbh and canopy configuration.

Collectively, Maria recorded 8,565 faecal pellets beneath (and sometimes beyond) the canopies of the 30 trees (mean dbh of sampled trees: 40.51cm \pm 24.67(SD), range 95 – 895; mean no. faecal pellets tree⁻¹: 285.6 \pm 341.8(SD), range 1 – 1433). From these data it was able to be demonstrated that (i) *P. cinereus* faecal pellets were not uniformly distributed beneath the tree canopy, but (ii) they occurred most commonly near the base of trees (Figure 1).

Given the problems of accumulated faecal pellet counts, one of us (SP) then asked of Maria's

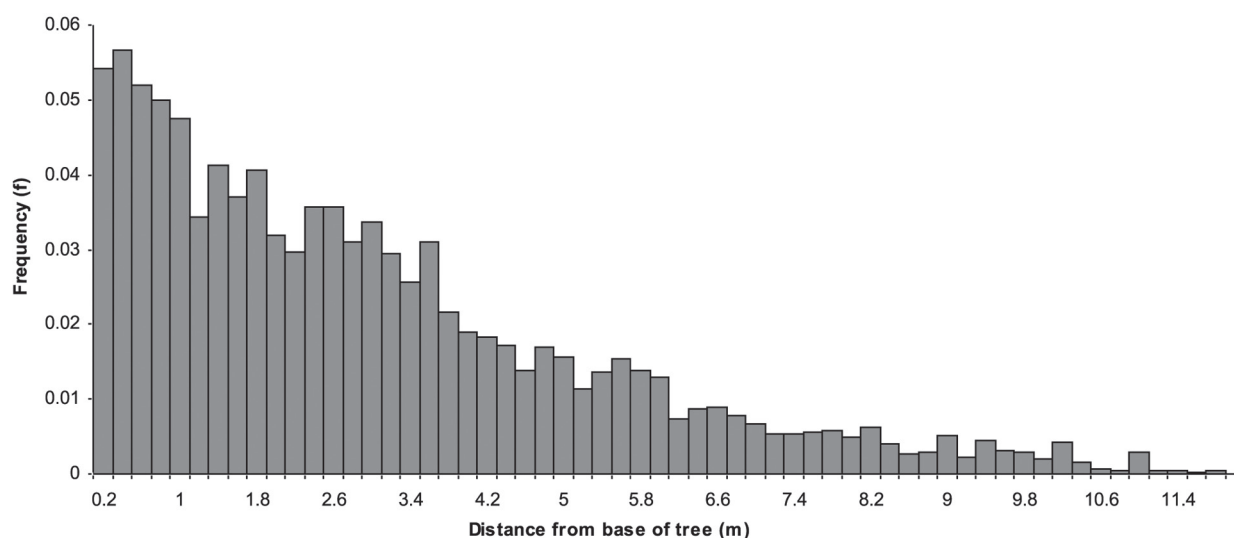


Figure 1. Pooled frequency histogram illustrating the distribution of *P. cinereus* faecal pellets as a function of increasing distance from the base of 30 sampled food trees (Source: Jones 1994).

APPENDIX I

data: “Given that each tree is a spatially independent replicate, what - on average - is the relationship between proportion (p) of the total faecal pellet count beneath each of the sampled trees as a function of distance from the base?” Figure 2 illustrates the answer to this question, demonstrating how the probability of success in terms of actually finding pellets can be related to the size of a radial search area. With this knowledge it then became a matter of looking for a search parameter that combined a meaningful probability of encountering one or more faecal pellets, yet also restricting the

search to an area that could be efficiently worked. Further interrogation of the data established that, on average, the equivalent of $47\% \pm 12\%$ (95% CI) of all *P. cinereus* faecal pellets will be located within a distance of 1m from the base of trees that have been utilized by the species. We figured the odds at that distance (i.e. ~50:50) were good. While a smaller search area (i.e. 0.6m) would clearly have increased search efficiency, the probability of finding pellets was almost halved! Conversely, increasing the search area beyond 1m resulted in not just minor increases in the probability of success but also substantively increased the search area in each instance.

The results of the preceding analysis are generally in accord with the observations of other workers, Ellis et al (1998) also recording a disproportionately high density of pellets adjacent to the trunks of some trees utilized by *P. cinereus*, with approximately 18% of daily collection falling within a 1m x 1m area around the tree base. Sullivan et al (2002) used a 30cm search area around the base of trees, reporting a variable tendency (1.9 – 13.5%) for misclassification (i.e. recording absence when in fact pellets were actually present elsewhere beneath the canopy). Interestingly, the potential for such misclassification is strongly supported by Figure 2 which otherwise infers that the proportional representation of faecal pellets using a 30cm basal search area is very low (~10-15%).

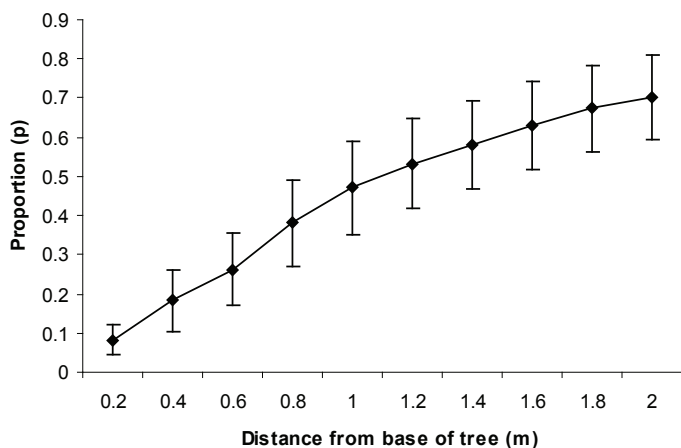


Figure 2. Mean proportional representation (\pm 95% Confidence Interval) of the total faecal pellet counts from beneath a sample of 30 trees known to have been utilised by *P. cinereus* (raw data sourced and re-analysed from Jones (1994)).