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HABITAT ASSESSMENT AND KOALA REVIVAL PROSPECTS IN THE EUROBODALLA – A PILOT STUDY

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Eurobodalla Koalas project
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IN THE EUROBODALLA –
A PILOT STUDY (January 2013)

CONTENTS

Purpose of this document

This report describes the volunteer Eurobodalla Koalas project pilot study (2012).

The pilot study established a theoretical basis, constructed a predictive habitat model for enquiry and analysis, and drew some conclusions after a year of testing through a literature search, fieldwork sampling and preliminary Geographic Information Systems (GIS) mapping.

The pilot study was intended as a structural beginning for a future, more sophisticated research effort. This report's intended audience is therefore researchers and practitioners engaged with the koala and related flora and fauna in fields such as biodiversity, farming, forestry and urban planning. Despite the theoretical content however, it also records a lay community approach to the subject and can be used as a starting point by lay persons interested in pursuing koala or multi-species habitat conservation.

The authors hope this document will contribute to engagement between land management stakeholders about habitat conservation and potentially a Eurobodalla koala recovery strategy. They invite evidence-based criticism of the pilot study, its theoretical model, methods, choices of references, findings and recommendations.

Although not designed as a funding application, this report or selected parts are likely to be cited in support of funding applications.

The publisher, *The Coastwatchers Association Inc.*, initiated the volunteer Eurobodalla Koalas project and allocated modest resources through its tax deductible Environment Fund. *Coastwatchers* can be expected to use this report as evidence in support of its core business: nature conservation advocacy.

Abstract

Koala numbers declined in the Eurobodalla (NSW South Coast) Local Government Area (LGA) throughout the Twentieth Century, to the point where sightings are extremely rare and localized extinction might now threaten. Disagreements between the conservation movement and the forestry industry, lack of data, lack of attention to broad-scale connectivity corridors in relation to local government planning, and naive community attitudes towards koalas are reasons why a controlled scientific study is needed.

The LGA has disproportionately large State Forest (actively logged) and National Park tenures by comparison with many other LGAs, as well as farming, semi-rural living and quickly growing urbanized towns. There is also past history of vigorous gold mining in known koala areas. The landscape ranges from the Eastern seaside, through rural hinterland and wilderness to the high escarpment, part of Australia's "Great Eastern Escarpment". There are three major river catchments. Known low density koala populations still exist in adjacent LGAs (Bega Valley, Cooma-Monaro and Shoalhaven).

An exploratory predictive habitat model grounded in ecological theory was implemented by a small volunteer community group, to estimate the extent to which the Eurobodalla landscape might still sustain a low density koala population.

Data and information were collected through: (i) a literature search; (ii) Geographic Information Systems (GIS) map analysis, using polygons from the well-known SCIVI map and their floristic descriptors; and, (iii) field-based surveys using the Regularised Grid Based Spot Assessment Technique (RGBSAT), a device for estimating koala numbers through scat searches which also doubles as ground-proofing for a patch about the size of one pixel in a *Landsat* image. Amongst the wider range of material on related subjects, literature addressing habitat for low density koala populations, especially eucalypt browse species, was used to mediate cross-referencing between the GIS vegetation type map analysis and the twenty-one field survey plots. The purpose was to discover whether viable home range patches and connectivity for breeding might still exist in the Eurobodalla, based on the mix and distribution of extant eucalypt species. The pilot study did not have time to include other apparent habitat determinants in its analysis, such as altitude, slope and aspect of topography, proximity to water sources, microclimate and disturbance. These, plus utilization of a proper statistical control in the pilot study's GIS analysis would be necessary to ensure confidence in the validity of conclusions.

The literature search enabled endemic Eurobodalla eucalypt (and relevant corymbia and angophora) species to be categorized according to their apparent relative importance as koala browse species in a low density population context. Twelve species (of which koalas elsewhere appear to use at least two in the browse mix at any one time) were classed as "Primary". Ten species (of which koalas elsewhere appear to use at least three in any browse mix) were classed as "Secondary". Eight species were classed as "Supplementary". Three species were classed as "Suspected". A further three species not mentioned in the research literature but very similar to others used by koalas were considered when predicting the potential habitat mix.

Vegetation types displayed as polygons in the SCIVI map, and those discovered in the field surveys, were checked against these species categories. Polygons displaying potentially viable species mixes were identified and viewed collectively to permit judgments on the whereabouts of potential home range areas and connectivity corridors.

Although theoretical testing generated inconsistencies when eucalypt types in the RGBSAT survey plots and SCIVI polygons were viewed separately, when the eucalypt results for survey plots and their associated polygons were viewed together, nine polygons (seven vegetation types) were clearly rated as having very good potential habitat, five polygons were rated good, three fairly good, two were regarded as suitable only if their adjacent vegetation type was also taken into account, one polygon contained only a mix of "Supplementary" species, and one polygon was rated as being no good at all for potential low density koala habitat.

The pilot study itself does not possess the robustness to draw conclusions in respect of its hypothesis (*the landscape, with appropriate protections, will sustain a revived low density koala population*) and null hypothesis (*the landscape will not sustain a revived population regardless of protections*), but has provided some preliminary indicators about the probable status of koalas in the Shire and in respect of eucalypt species at least, the status of prerequisite home range and connectivity conditions.

Except for two reported August 2012 sightings at one location, which might represent a dispersing animal, no clear evidence was found of koalas persisting in the Eurobodalla since 2009. The impression from formal records and local knowledge was that Eurobodalla koala numbers, always sparse since the mid-20th Century, were at a critical point by about the year 2000.

The pilot study's exploratory derived GIS map appears to show larger patches of higher quality potential browse species mix in the Shire's South East (Moruya and Bodalla State Forests), and medium quality potential browse species mix in the Shire's West (Deua National Park). These patches appear large enough to sustain low density resident groups. Connectivity between Eurobodalla patches and with patches in adjacent LGAs appears variable. Large areas of low quality potential browse species mix appear across the Shire. There appear to be small isolated pockets of remnant high and medium (as well as low and nil) potential browse species mix scattered elsewhere across the landscape. All these conclusions need to be revisited through a more robust analysis, however.

The authors are confident the research model tested by this pilot study is adaptable to a larger future study. It was deemed capable of examining potential habitat for koalas in low density circumstances across the Eurobodalla landscape (and elsewhere) by incorporating the full range of habitat factors with an enhanced statistical control in its GIS analysis component.

It is recommended that such a full study be pursued, comprising a large number of RGBSAT survey plots at strategically selected places, and refinement and expansion of the pilot study's GIS analysis using the latest available vegetation type polygons, preferably with direct technical input from expert agencies holding contemporary data, such as Forests NSW and the Office of Environment and Heritage. Such a study would put to rest any question about localised functional extinction and could include a recovery strategy design.

Introduction

Project aim

The aim of this study was to predict the extent to which the Eurobodalla landscape will sustain a low density koala population.

Need for the study

There is a very small group (estimated at five to fifteen animals based on scat survey data) at Sam's Ridge (near Dignam's Creek, Bega Valley Shire) adjacent to the Eurobodalla Local Government Area (LGA) border, and two reported August/September 2012 sightings at Cadgee (within the Eurobodalla LGA) of a possibly dispersing animal. Apart from that, evidence since the previous two 2009 reported sightings near Nerrigundah has prompted a suggestion of possible localized near-extinction (or "functional extinction") of the koala within the Eurobodalla LGA; yet, in this Shire people still remember seeing them (see *Local history*, below). Whether an extinction assertion can be made with validity has been questioned because of the lack of comprehensive surveys, especially in the large State Forest and National Parks tenures.

The post-Nineteenth Century context is one of very low koala numbers in the NSW South East, so scientific emphasis is on low density populations and their capacity to adapt to "non-core" habitat. By comparison with regions where population density is higher, this is a difficult research field for attracting funding and policy priority. What was essentially conservative advice to the Commonwealth Minister from the National Threatened Species Scientific Committee on amendment to the list of threatened species (2012) [1] notes:

> "*A synthesis of recent koala surveys was prepared for the purposes of this nomination by Chris Allen of NSW DECCW, combining the results of surveys conducted using a variety of means (Allen 2009). Densities for all areas were uniformly low or very low. The combined estimates for the region from approximately Goulburn south to the New South Wales border sums to approximately 800 koalas. Allen (2009) notes some indications of an increase in the population in the coastal forests north east of Bega, but it must be noted that this is an extremely small population. Recent intensive surveys show that a population at Tantawangalo/Yurammie is now very low and possibly extinct*." (p. 22)

Reaction amongst the general public to a suggestion of localized extinction in the Eurobodalla Shire ranges from denial ("you can't say that"), through surprise ("there must be koalas there – there's so much forest"), to resignation that another iconic native species is sadly gone and nothing can be done about it. There are assumptions and traditions, but little informed discussion about the impact of contemporary human population expansion, urban/peri-urban development and other disturbance factors (other than a high profile political conflict over the role of forestry, mainly centred around Bega and Eden to the South of the Eurobodalla) on the pre-existing koala population. Aspects like the future potential of habitat or whether a recovery strategy is warranted, do not appear in the public discourse of the Eurobodalla. On the other hand, in mid-2012 the decision of Commonwealth Minister Burke to list NSW koalas as "vulnerable", combined with the announcement of successful Commonwealth

Biodiversity Fund projects focusing on the adjacent Bega Valley LGA habitat, prompted some media attention and some excitement amongst certain government agency staff. There was a small surge of local print and radio media interest just after this time, coinciding with new koala evidence from surveys in Tanja State Forest (Bega Valley Shire).

Public controversy about the role and intensity of the contemporary State Forests logging regime under the Regional Forest Agreement, polarises the question of habitat damage. On the one hand there is criticism from the environment movement about over-logging, premature logging, an unsustainable commercial model with below world parity woodchip prices propped up by government taxpayer subsidies, lack of valid data, licence breaches, lack of adequate supervision, lack of transparency and lack of accountability. On the other hand the forestry industry defends its resource as renewable, and its practices as sustainable, part of the solution to climate change, and a vital component in the local economy and the survival of local communities. There is also occasional criticism about the lack of resourcing for National Parks and Wildlife Service (NPWS) to implement a conservation charter. In addition there is lobbying against any assumption that primary producers should shoulder responsibility for conserving and rehabilitating koala habitat, combined with a political debate at local government level about environmental and biodiversity land zonings under the Local Environment Plan (LEP). At the time of this study the NSW Government was reviewing regulations governing native vegetation clearing on private property. Urban and infrastructure development is continually reducing habitat.

Amongst researchers and practitioners, the inadequacy of historical koala records and surveys, except for those required under the Regional Forest Agreement Threatened Species Licence (themselves subject to dispute), is acknowledged. The lack of a landscape-scale multi-species connectivity plan is acknowledged by some. Amongst the small group actively interested in the issue, there is questioning about the necessity, cost-benefit and feasibility of translocating koalas from over-populated bottleneck populations elsewhere to the Eurobodalla's National Parks.

To aid clarity and provide a dispassionate basis for planning, a controlled, contemporary scientific study is required. This will set the grounds for the viability of the translocation or natural revival options, through defining suitable habitat and considering threats to koalas.

Gaps in research

The key gaps in koala research for the Eurobodalla can be summarized as:

- insufficient historical or current koala population data;
- the need to increase contemporary (post-1990's) research on low-density koala adaptation to the full range of eucalypt species;
- lack of clarity on definitions of core and potential habitat, and the roles of primary and supplementary browse species;
- lack of mapped cross-tenure home range areas and connectivity amongst biodiversity zones, protected zones and/or biodiversity corridors which have already been identified;
- lack of a comprehensive, cross-tenure koala recovery strategy.

How the study addresses these research gaps

The pilot study has begun to fill these gaps by testing a “predictive habitat model”, whereby field survey data, the most recent available maps of Shire-wide vegetation types and contemporary literature are queried and cross-referenced in a structured analysis.

This was necessarily a modest pilot study because it has been led by a small group of volunteers with minimal funds.

Background

Koala numbers declined in the Eurobodalla throughout the Twentieth Century, to the point where sightings are extremely rare and localized extinction now threatens. The LGA has large State Forest (actively logged) and National Park tenures, as well as farming, semi-rural living and urbanized towns. There is also past history of vigorous gold mining in known koala areas. The landscape ranges from the Eastern seaside, through rural hinterland and wilderness to the high escarpment, part of Australia’s “Great Eastern Escarpment”. There are three major river catchments, the Clyde, the Moruya/Deua and the Tuross. Other smaller but significant catchments surround coastal salt water lakes, such as Wagonga Inlet (Narooma). Known low density koala populations exist in adjacent LGAs (Bega Valley at Bermagui, Mumbulla and Tanja, Cooma-Monaro at Numeralla and stretching northwards towards Michelago, and Shoalhaven in the Morton and Bungonia National Parks).

A beginning point for the pilot study can be found in the volunteer Eurobodalla Koalas project discussion paper (March, 2011) [2], including the local context, issues and most of the pre-2012 concepts, sources and materials (see also *Hypothesis*, p.27, below).

Subsequent to the discussion paper’s release:

- the Senate Inquiry into the status, health and sustainability of Australia’s koala population [3] concluded, its most relevant outcome being its aggregation of available information;
- the small number of Sam’s Ridge koalas (considered by the NPWS survey practitioner to be critically endangered, and probably connected to the Bermagui population) were found to be active in the upper Kooraban National Park where it crosses the Bega Valley border into the Eurobodalla (Allen, 2011) [4], and the 2012 Cadgee sightings occurred;
- new findings about population density, habitat and genetics were emerging in the neighbouring Cooma-Monaro (Southern Tablelands) surveys, the new evidence of koalas occupying Tanja State Forest (Bega Valley Shire) emerged, and substantial Commonwealth Biodiversity and NSW Environmental Trust funding were made available for those Shires’ koala habitats; and,
- better knowledge about the translocation issue was gleaned from meetings with the Far South Coast Region Advisory Committee on National Parks and with the local State Government member and the relevant Eurobodalla Shire Councillor, as well as a Bega Valley Shire translocation feasibility study [5] not yet made public at the time of editing this report.

Literature Review

Theory and methodology

As mentioned in the preceding chapter, the pilot study cross-references a set of field surveys with a multi-layered Geographic Information Systems (GIS) map, mediating its analysis through a contemporary literature search. The research approach is considered a "predictive habitat" model.

Theoretical field

The pilot study was generally grounded in ecological theory. Odum and Barrett (2005) provide a concise overview of the *scope of ecology* (eg the levels-of-organisation hierarchy, from the ecosphere to the cell), the *history of ecology* (eg cellular, molecular and population research, and the emergence of mass chemistry, mathematic modeling and Geographic Information Systems - GIS) and the *relevance of ecology* (eg holism, reductionism, synthesis and transdisciplinary approaches as ways of giving appropriate attention to organism, population, and community subsets and to landscape, biome and ecosphere suprasets) [6]. Austin (2002) provides a useful link between the basic principles of ecological theory and this pilot study's construct, exploring vegetation models, species models and several types of statistical models. Austin's is a detailed analysis of the field and a critique of different approaches, their strengths and shortcomings. Austin explains the need for an ecological model concerning the ecological theory to be used or tested. Austin observes the need for two other design components when statistical models are devised, grounded in ecological theory: a data model concerning the collection and measurement of the data; and, a statistical model concerning the statistical theory and methods used [7]. Austin's approach shows how theoretical models and methodologies flow from the underlying ecological concepts outlined by Odum and Barrett (see *Theoretical Model*, below).

The choice of subject (the koala and its habitat) refined and further located the study in the subordinate theoretical field of ecosystem ecology. Chapin, Matson & Vitousek (2011) [8] provide a conceptual basis for understanding terrestrial ecosystem processes. Their cited South Florida (restored Everglades) example (*p.438*) directly informs the Eurobodalla Koalas concept, employing a spatially explicit hierarchical landscape model in which models of higher trophic-level indicator species use information from models at intermediate trophic levels (eg fish) and lower trophic levels (eg macrophytes). The species-specific models are then layered on a landscape GIS model that includes hydrologic and abiotic factors such as surface elevations, vegetation types and soil types. The end purpose is simultaneous success of multiple species, implying health of the overall ecosystem (see *Hypothesis* – *Rationale*, p.27, below).

The study's analysis of the relationship between the conditions of habitat and potential koala population revival positioned the focus within systems ecology. Odum & Barrett [op cit, *Chapter 1, Section 2*], explain how a multilevel approach brings together "evolutionary" and "systems" thinking. Sub-disciplines like population dynamics, competition, biodiversity ecosystem analysis, energy ecosystems analysis, material cycles etc, can be linked to each other and to the biology of organisms, underpinning models for the study of how individual organisms and species interface and use resources. So, in systems ecology, experimental studies are linked to sophisticated theory and models.

This pilot study's community mapping and ground-proofing methodology utilized spatial ecology and to some extent biometric techniques. Thornton, Branch & Sunquist (2010) [9] offer a spatial ecology review as follows:

> "*We reviewed 122 focal patch studies on 954 species published between 1998 and 2009 to determine the probability of species responding significantly to landscape, patch, and within-patch variables {*our underlining*}. We assessed the influence of taxonomic, life history, and methodological variables on probability of response to these 3 levels. Species in diverse taxa responded at high rates to factors at all three levels, suggesting that a multi-level approach is often necessary for understanding species response in patchy systems. Mammals responded at particularly high rates to landscape variables and therefore may benefit more than other taxa from landscape level conservation efforts in fragmented environments. The probability of detecting a species response to landscape context, patch, and within-patch factors was influenced by a variety of methodological aspects of the studies such as type of landscape metric used, type of response variable, and sample size.*" {Online Abstract}

The latter observation also offers a caution about methodological pitfalls (See *Theoretical Model*, below). Numerous references on the basics of biometrics (the measurement of biological data) are available, eg Jain, Flynn & Arun (2008) [10].

Theoretical model

J. Michael Scott et al (2002) [11] discuss sources of error in studies using habitat models (of which they reviewed hundreds), and provide advice on ways these errors can be averted in research and management decision making when time and other resources are constrained. Scott et al advocate a clear construct and the application of simple tests drawn from fuzzy sets theory. This pilot study's researchers made the following choices amongst the "three important aspects" Scott et al (*p.129*) describe for "constructing multi-scale models of complex wildlife-habitat systems". It was reasoned that the chosen model, combined with ongoing attention to the null hypothesis and a peer review process, strengthened validity and further diminished researcher bias in this pilot study.

The first of the three important aspects posited by Scott et al is the philosophical approach used to assess the relationship between scales and levels: "inductive" if levels are inferred from the data, "deductive" if data are used to test predictions about processes inferred logically from a theoretical model describing levels. This pilot study's philosophical approach was considered inductive according to these descriptors, because levels were to be inferred as accurately as possible from limited available data.

The choices proffered within the second important aspect, model type, provide a framework for decision making about a useful and valid model. In terms of the Scott et al descriptors, "mechanistic" models describe the details of organismal life histories, "population/metapopulation" models describe vital rates or colonization/extinction rates, and "statistical models" are used to establish correlations between habitat features and population patterns. The researchers were comfortable in considering their predictive pilot study of habitat and koala revival prospects, through mapping and field surveys, as largely a "statistical" model according to the Scott et al terminology although much of the analysis was non-statistical. Indeed, it is recommended that future research using this pilot study model should incorporate a fully integrated, detailed statistical component. The steps for doing so are suggested in *Further Improving the Method*, below (p.63).

The third aspect Scott et al regard as important for avoiding error in studies using habitat models, is the modeling goal: "statistical description" if the model is evaluated with data used to estimate its parameters; "statistical prediction" if the model is evaluated with data not used to estimate its parameters. This pilot study fitted the statistical prediction model type.

In respect of the "simple tests" recommended by Scott et al, this study's application of "three overlapping fuzzy sets" (see overview in *Mathworks Toolbox* [12]) (to each of which the associated fuzzy set formula *Intersection=min{A,B,C}* was to be applied [*formula adapted from* Scott et al, *Pp. 100 & 106*]), encompassed:

1. the layers in the GIS* map
2. the consistency of the map with the RGBSAT** plot survey results
3. any scats or records of koala presence found in relation to the eucalypt types inventory within each RGBSAT survey plot or vegetation type polygon

The additional application suggested by Scott et al ("accuracy tests") involved graphing convergence of map and survey results for suitability values against the hypothesis (while also keeping the null hypothesis in mind), thereby:

1. assessing potential habitat rather than forecasting actual abundance or occurrence of the species (*p.104*)
2. assessing the degree to which the model of potential habitat overestimates the potential for the species to occupy the geographical area (*p.105*)

Upon implementation of the pilot study's two methodological components the fuzzy sets and accuracy tests were positioned against each category. Appendix 1 records the testing exercise schematically. These tests were important in checking for logical pitfalls associated with the mapping, survey and cross-referencing methodology, and should continue to be refined and utilised in any larger subsequent study, as cautioned by Scott et al:

> *"The most significant sources of error [when using habitat models] are (1) the use of discrete thresholds for convenience when these are not supported by either theory or evidence, and (2) the use of an inappropriate mathematical operation to produce output values from a habitat model. These errors are particularly important in determining the appropriate geographic area needed to conserve a given species' habitat. In situations where discrete thresholds are used inappropriately, geographic boundaries are introduced in the mapping of management zones that are actually just data artifacts, with no clear connection to a theoretical framework. Frequently these reified boundaries are misinterpreted as having genuine biological meaning – particularly when many map layers have been combined in an analysis and the source layers where these data artifacts originated are no longer individually visible…."* {*p. 105*}

* *GIS: Geographic Information Systems*
** *RGBSAT: Regularised Grid Based Spot Assessment Technique*

Two components of methodology were chosen for this model, both of which have a significant body of research.

GIS literature

The first component was to map koala habitat using *Geographic Information Systems (GIS) technology*. GIS provides a sophisticated method for overlaying multiple layers of spatial data (eg maps), and linking them with attribute tables to display and analyse results. GIS is especially suited to habitat modeling and has built-in statistical strengths. *ArcGIS* software (Ormsby et al, 2009 [13]) was chosen for its compatibility with that used by the NSW Office of Environment and Heritage, Eurobodalla Shire Council, Forests NSW, Southern Rivers Catchment Management Authority, the University of Canberra Applied Science Faculty and the Canberra Institute of Technology (CIT). *ArcGIS* is widely used in the scientific community, possessing high credibility and featuring frequent updates.

Relevant prior GIS work was noted, including Victorian Government research [14], connectivity model building for specific species by the Arthur Rylah Institute (Melbourne) [15], Norton and Nix (1991) [16] and Australian National University (ANU) mapping studies around Kioloa including Hammond's (1997) prediction of koala habitat there [17]. Hammond analysed 2,800 square kilometres between Jervis Bay and Batemans Bay (where koala sighting records are also sparse), an area selected for the availability of spatial data rather than information concerning koalas. Climatic domains, nutrient status, slope suitability, distance from a streamline, shade and shadow and disturbance were spatially represented in a GIS. The climatic domains of identified tree species formed "sub-model" areas. Other attributes were classified using fuzzy set methods with identified limits, and then…

> *"masked for the sub-model areas. The most exclusive value for a cell taken from all input attributes was taken as the output cell value. This produced a grid that displayed predictions of high-quality potential habitat for the Koala. The predictions were tested in the field. The number of sites checked were not enough to conclusively prove the ability of the model to predict high-quality potential habitat for the Koala. However it does suggest that the habitat does occur in areas that agree with the conceptual model. The results show that the predictions of high-quality potential habitat for the Koala match the field surveys well.*
> *There were very few areas predicted to provide high quality habitat…"*
> {Abstract}

Directly relevant to this pilot study's questions and methodology was the Comprehensive Regional Assessment (CRA) predictive modelling, reported by Gellie (1998) [18]. The process utilised *ArcView Spatial Analyst*. The modelling is discussed in more detail under *Local History* and *Suitable range areas and adequate connectivity corridors* (Pp.18 and 39, below).

The pilot study's GIS mapping concept was also informed by a collection of other scholastic publications, including the predictive habitat models and referencing of appropriate GIS statistical devices reported by Gibson, Wilson, Cahill & Hill (2004) who developed a predictive spatial model of endangered rufous bristlebird habitat to identify critical areas requiring preservation, such as corridors for dispersal. The researchers generated habitat models using generalized linear modelling techniques coupled with Geographic Information Systems (GIS) technology to produce maps displaying the spatial configuration of suitable habitat. Their models used:

> *"logistic regression, with bristlebird presence or absence as the dependent variable and landscape variables, extracted from both GIS data layers and multispectral digital imagery, as the predictors. A multimodel inference approach based on Akaike's information criterion was used and the resulting model was applied in a GIS to extrapolate predicted likelihood of occurrence across the entire area of concern. The predictive performance of the selected model was evaluated using the receiver operating characteristic (ROC) technique. A hierarchical partitioning protocol was used…"* [19]

In a "population model" more sophisticated than, but displaying some underlying similarities with the "predictive habitat" approach of this pilot study, Osborne, Alonso & Bryant (2001) present predictive models for great bustards in central Spain based on readily available advanced very high resolution radiometer (AVHRR) satellite imagery combined with mapped features in the form of Geographic Information Systems (GIS) data layers:

> *"As AVHRR imagery is coarse-grained, we used a 12-month time series to improve the definition of habitat types. The GIS data comprised measures of proximity to features likely to cause disturbance and a digital terrain model to allow for preference for certain topographies. We used logistic regression to model the above data, including an autologistic term to account for spatial autocorrelation. The results from models were combined using Bayesian integration, and model performance was assessed using receiver operating characteristics plots."* [20]

Zabel et al (2003) [21] describe a best-fitting predictive model, evaluating the relationship between owl occupancy and the quantities of different habitat metrics & scales. They began by comparing different habitat descriptions using predictive habitat-association models.

The Starkey Habitat Database for Ungulate Research (Rowland et al, 1998) [22] is another useful "how-to" document in this field.

Store & Kangas (2001) [23] provide a good reference for the more advanced statistical aspects of modeling with GIS, that this pilot study recommends for use in any future full study.

Closer to home, Chris Allen's report to the Threatened Species Scientific Committee (2010) [24] mentions the GIS tool *regularized splining* (in the *ArcGIS* extension *Spatial Analyst*) used to delineate "activity contours" in his Far South Coast surveys:

> *"Based on the data collected in this survey a GIS mapping tool (regularized splining) delineated activity contours and cells and provides the basis for the population estimates in the study area. The activity contours were derived from the activity levels at each of the sites assessed, and those of their 12 nearest neighbouring sites. Contouring of model output was subsequently applied in order to identify and isolate the 2, 3 & 9% activity contours. For*

modeling purposes, unsampled sites surrounding those sampled were given a default zero activity level." (Pp. 14-15, including map)

An important document for National Parks and Wildlife research on habitat corridors and assessing connectivity within GIS is Scotts (2003) [25], also discussed under Suitable range areas and adequate connectivity corridors (p.39, below). To address connectivity within the GIS, Scotts' method:

> *"acknowledged the importance of matrix areas as significant connectivity components but proposed to compile a regional depiction of particularly important connectivity elements (corridors) by accumulating the connectivity value of many individual potential landscape linkage pathways…..*
> *The GIS tool NPWS CORRIDORS (CORRIDORS) was used to map potential linkage pathways linking both within and between predicted assemblage distributions…" (Refer Scotts, pp. 45-55 for detail)*

RGBSAT and other survey literature

The second methodological component in the pilot study was the sample of field surveys to scat-search and vegetation-ground-proof potential habitat, using the *Regularised Grid Based Spot Assessment Technique (RGBSAT).* Phillips and Callaghan (2000) [26] describe RGBSAT as a tree-based sampling method which utilizes binary data derived from the presence/absence of koala faecal pellets within a prescribed area beneath trees to determine whether the use of a given area of habitat by koalas is important. The importance of trees is analysed as follows:

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

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 100mm or greater*".

The RGBSAT method was used in the NPWS Bermagui/Mumbulla (2010) [27] and Kooraban/Gulaga (2011) [4, op cit] surveys and was also being used in the Cooma-Monaro (Southern Tablelands) and Tanja surveys at the time of conducting this pilot study. Based on those surveys and advice of the practitioner, this pilot study used minimum DBH of 150mm.

CSIRO publications contain previous material on various types of, and issues related to scat searches. Examples are *Ellis et al* (1999) [28], *Common & Horak* (1994) [29] and *Sullivan et al* (2003) [30; 31]. Survey methods other than RGBSAT are discussed by *Lunney et al* (2009) [32] who looked at a community mapping model, and others such as the "transect with quadrats" method are contained in the regulated practices of Forests NSW [33]. *Curtin et al* (2001) [34] and *Dique et al* (2003) (evaluating "line-transect" method) [35] offer additional insights.

Koalas – prior research

Five decades of scholastic materials on koala history, behaviour, rehabilitation and habitat are available as background to this pilot study and have relevance for resulting follow-up research. CSIRO journal articles, for example, range from ecological studies (*Gall, 1980* [36]) through details of feeding behavior (*Logan & Sanson, 2003* [37]) to distribution (*Radford et al, 2006* [38], *Munks et al, 1996* [39], *Sullivan et al, 2004* [40], *Harris & Goldingay, 2003* [41], *Dique et al, 2004* [42] and *Dique et al, 2003* [43]), population decline in specific landscapes (*Every, 1986* [44] and *Martin, 1985* [45; 46; 47]), morbidity (*Backhouse & Bolliger, 1961* [48]), and climate change and drought (*Adams-Hosking et al, 2011* [49] and *Seabrook et al, 2011* [50]).

The community based postal survey in the Eden Region, undertaken by Lunney et al in 1991-1992 [51] elicited 1,198 replies from 11,600 households and found:

- *koalas are rare in the Eden Region;*
- *the number has been constantly low for the "last four decades" [since the early 1950's];*
- *records are scattered both chronologically and geographically;*
- *National Parks and Nature Reserves have never been the stronghold of local koala populations;*
- *freehold land, particularly farmland, is not a major reservoir of koalas;*
- *most koalas reported were in, or adjacent to, State Forests particularly Murrah-Bermagui and Tantawangalo-Glenbog-Yurammie;*
- *dry forest is the preferred habitat;*
- *the once abundant and widespread koala population of late last century has been reduced by habitat loss and fragmentation to a few small, isolated populations.* {Abstract}

The subsequent Forests NSW research at Eden presented by Jurskis and Potter (1997) [52] has played an important part in local practitioners' and researchers' discussion, and appears to have been influential in policy making. The study looked at data obtained between 1990 and 1997, viz:

- seasonal taped playback of male koala calls as a method allowing sites to be targeted for more intensive systematic surveys;
- koala use of trees and forests;
- physiology;
- genetics; and,
- radio-tracking studies.

Jurskis and Potter concluded that:

- there was an association of koalas with dry and/or disturbed forests at Eden;
- no dense aggregations of koalas were identified in the area;
- the radio collared koalas had established home ranges – "*although these were larger than many described in the literature, their size was comparable with some reported for low density populations in Queensland;*
- *forestry operations have provided the main impetus for koala research;*
- *there is evidence that forestry may not impact detrimentally on koala populations and may have beneficial impacts in the long term;*
- *there has been little koala survey or research conducted in national parks or private land at Eden;*
- *community groups and academic institutions should be encouraged to redress this imbalance;*

- *it is unlikely that dense koala populations will occur in the Eden area unless high carrying capacity habitats are re-established on suitable sites;*
- *suitable sites may occur on private lands which have mostly been cleared in the past for agriculture and urban development*" {Summary}.

In a recent report commissioned by the National Association of Forest Industries (NAFI), Tucker and Wormington (undated) [53] provide a good review of koala status and issues and a substantial up-to-date reference list, but draw conclusions that are so clearly supportive of the NAFI case that the conservation movement is sceptical:

> "*With the long term sustainability of forest industries being dependent on the maintenance of multiple-use timber production forests, koalas have the opportunity to simultaneously utilise and take advantage of these habitats. Some of the now forested areas in Victoria which are important Koala habitat were planted for timber production (between 1930 and 1950) after being completely cleared for farming or broadacre logging. In NSW the regulated timber industry ceased land clearing on vast estates after extensive areas were completely cleared for agriculture and livestock. In many of these areas koalas may have become locally extinct without the habitat provided by the industry….*
> *The very limited research to date shows no overall effects on koala populations from timber harvesting activities in forests, due to logged forests being regenerated or the establishment of plantations (of Eucalypts) which restores habitat. This, as well as the current procedures to preserve koala use areas and provide buffers and corridors to un-harvested areas in NSW and the preservation of riparian and corridors in Victoria, provides opportunities for koalas to exist with the logging activities. This is not the case of clearing on private or lease hold land, for urban development, agriculture and livestock, as the land use permanently changes and there is no regeneration of forest/habitat, which is a much more significant loss for koalas." (p. 26)*

Regardless of one's assumptions, Tucker and Wormington offer useful information for this pilot study in a succinct overview, eg:

> "*Kavanagh et al. (2007) identified the importance of a minimum number of eucalypt trees per hectare for koala habitat and suggested a minimum threshold of 20 eucalypt trees larger than 20 cm diameter at breast height (DBH) per hectare to maintain habitat quality. Similarly, in the Eden State Forest, research recommended the retention of koala habitat to include "browse tree species in sizes greater than 30cm DBH" (Jurskis, 1997). Studies done at Pine Creek State Forest (6400ha in north-east NSW) showed a variation in koala density among different forest structures and harvesting history. Koala preferred structurally complex (uneven ages, with old growth elements, and high species diversity) forests. Habitat preferences favoured areas with larger trees (40-80 DBH) (Smith 2004)." (p. 24)*

and

> *"There is evidence from south eastern New South Wales that the State Forests in the Eden region contain the core of the remaining koalas of the region (Crowther et al. 2009). However, these koalas have not been investigated fully and little is known about the impact of forestry activities on their survival"* (*p.25*)

and

> "*A multi-catchment survey in NSW supports this (sic) localised, catchment approach to the management of koalas, showing that a broad (multi-catchment) approach is not sufficient (Crowther et al. 2009) and a more effective koala management approach should be developed at a catchment scale rather than at a broader region or state level.*" (*p. 17*)

Late in the analysis phase of this pilot study, Heather Gow-Carey's 2012 Honours thesis [54] examining koala habitat south of the Eurobodalla, became available. Gow-Carey used data from the faecal pellet surveys conducted from 2007-2011 by NSW National Parks and Wildlife Service (Division of Office of Environment and Heritage) along with Forests NSW and extensive volunteer involvement. These surveys aimed to assess the distribution and abundance of the koala population. Approximately 21,000 hectares was surveyed from north of Tanja through to Gulaga National Park, north-east of Bermagui across multiple tenures including National Park, Nature Reserve, State Forest and private land. Based on these data, Gow-Carey undertook an investigation of overall habitat quality. Aspects of Gow-Carey's work are further referenced in <u>*Statistical literature*</u>, below and later in this report at <u>*Geographic Information Systems (GIS) map*</u> and <u>*Suitable range areas and adequate connectivity corridors*</u>.

<u>Local history</u>

Available historical reports, local knowledge, landscape and vegetation features suggest the Eurobodalla was a natural home to koalas in the Nineteenth Century until clearing for farming, hunting and other disturbances contributed to a marked drop in numbers.

Clear historical references specific to koalas in the Eurobodalla are very rare. One is Warry (1990) [55] who cites a report from a late Nineteenth Century traveller in the Deua River Valley. Blay (1987) [56] mentions a settler's recollection of plentiful koalas at Wyanbene/Big Hole (North-West of the Eurobodalla) in the year 1838 but koalas are not mentioned for the rest of Blay's 1981 journey through the Deua and Tuross back country. Townsend (1849) [57] describes koalas on Pigeon House Mountain (within sight of the Eurobodalla) in the mid-Nineteenth Century. Attention to koalas in Aboriginal heritage is given by Wesson (2003) [58]. Searches of NSW Government Archives provide glimpses into the koala skin industry up to 1924, but no direct references to the Eurobodalla.

The Shire still had remnant koalas in the wild during the Twentieth Century (NSW *Wildlife Atlas* [59]). Local residents assert koalas were close to the Moruya urban area eg Mogendoura in the late 1960s and Pedros Swamp in the 1950s. A Cadgee farmer asserts koalas were around her property until a Forests NSW incendiary-drop burn in 1983. A Donovan's Creek Road bush block resident asserts a koala walked across his back yard in the year 2000. More recent official records show koalas in National Parks (eg one 2000-2009 Wildlife Atlas record) and State Forests (eg one 1996-2000 record) [59, op cit]. Scattered records (confirmed and unconfirmed) like these exist for various parts of the Shire up until the early 2000s, but the last reported koala <u>sightings</u> within the borders of the Eurobodalla were two in 2009 and two in 2012, in State Forest near Nerrigundah and on the small Cadgee farm mentioned previously. The only scientific evidence of koalas persisting otherwise, is the survey result for 2011 suggesting a small critically endangered group might be occupying

Kooraban National Park North-West of Dignams Creek (*the Sam's Ridge area mentioned previously*) (Allen, 2011 [4, op cit]).

Forests NSW surveys in South-East Bodalla State Forest in May 2012 did not find evidence of koalas. The volunteer Eurobodalla Koalas project's 22 scat surveys in Autumn and Spring 2012 also found no convincing evidence, although a few scats remain unidentified. More comprehensive surveys are needed to show conclusively whether koalas are functionally extinct or near-extinct in the Eurobodalla LGA, but the currently available hard evidence suggests so.

During the first decade of the Twenty-first Century, the Regional Forest Agreement has been in operation, based partly upon pre-Year 2000 research which underpinned the characterisation of the Eurobodalla's forests as mainly "intermediate" or "marginal" koala habitat. This characterisation appears to have been based on the work of Gellie et al (1998) [18, op cit]. Gellie's report explains:

> "*The Eden fauna modelling project was undertaken to produce valid fauna models to predict the range of, and quality habitat for, fauna species of the area. These fauna models would then be used for the assessment of high quality habitat for significant priority species, and to provide digital information for other project areas for use in satisfying JANIS criteria (see Commonwealth of Australia, 1997) relating to centres of endemism, significant refugia, and areas of high biodiversity. External fauna survey data, collected during the Eden CRA fauna audit process, and data collected on the Eden CRA summer 1996/97 surveys, were collated and then validated by contracted experts in preparation for the modelling process. Abiotic and biotic environmental Geographic Information System (GIS) layers for the Eden CRA area were obtained. Various biotic and abiotic indices were calculated by contracted experts and contextual variables derived. All fauna species survey data were designated as formal (presence-absence) or incidental (presence-only) and survey method and effort covariates assigned to the formal data. Using S-PLUS and the completed fauna dataset and GIS layers, predictive distribution models were fitted for each species and their distributions extrapolated across the entire Eden area. For each model, statistics were derived indicating the degree of fit of the model to the data and the significance of each predictor (variable) used in the model. The maps produced indicated the probability of occurrence of each species across the Eden area from 1-100%. Models and maps for priority species (i.e. threatened and forest-dependent species) were evaluated by expert modellers and ecologists and revisions to the models made as necessary. The probability classes for each species' modeled distribution were grouped by the experts to reflect areas considered to be core, intermediate or marginal habitat. A number of species did not produce viable models due to lack of data or poor quality data. The final modelled distributions were later assessed and revised as needed by the CRA Response to Disturbance project expert workshops. The resultant modelled distributions from these workshops were used for the Conservation Requirements and Integration phases of the Eden CRA*."
> {Executive Summary}

Unfortunately however, this CRA work produced <u>no suitable model</u> for the <u>koala</u>. Gellie's report acknowledges several other shortcomings. A critique is included under <u>*Suitable range areas and adequate connectivity corridors*</u> (p.39, below), as part of this pilot study's contention that post-CRA research now needs to be applied in respect of predictive habitat modeling for koalas in low density circumstances.

Government documents

Comprehensive, contemporary overviews of the koala subject and related habitat/connectivity issues are in the National Conservation and Management Strategy (2009) [60], the NSW Approved Recovery Plan (2008) [61] and to a lesser extent the South Coast Regional Conservation Plan (2010) [62]. In August 2012, the ABC Television program "Four Corners" addressed topics ranging from diseases, hunting history, translocation and "functional extinction" to climate change [63].

The primary source for koala distribution records is the NSW Wildlife Atlas [59, op cit]. Others (eg Australian Koala Foundation mapping) are cited in the Eurobodalla Koalas project discussion paper [2, op cit].

In his submission to the Threatened Species Scientific Committee (2010) [24, op cit] Chris Allen, NPWS koala survey specialist for South East NSW, presents results for multiple surveys using different techniques between 1999 and 2009. For the coastal forests North East of Bega, Allen concludes:

> *"An occupancy rate of 10% in a study area of 21,000 ha suggests that approximately 2,100 ha of the area is occupied by Koalas. With home range areas of 50 -100ha, a population of 21 - 42 Koalas is suggested. This is only a tentative estimate, with some factors suggesting a higher estimate is warranted (e.g. Koalas will have overlapping home ranges, there may be unidentified activity cells) and others suggesting it should be smaller (e.g. the area derived using the occupancy rate data overall may be larger than home range areas, and home ranges may overlap)."(p.17)*

For Kooraban National Park, Allen concludes:

> *"…the relative ease (compared with surveys undertaken in coastal forests sustaining the Bermagui/Mumbulla population) in finding koala evidence and the presence of fresh and old scats at one of the sites, taken together with anecdotal reports of koala sightings, suggested that the Sam's Ridge area in the southern part of Kooraban NP, is also sustaining a breeding aggregation of koalas. These koalas occur within similar eucalypt communities as those sustaining the koala population some 10-30 km to the south east with a similar disturbance history. The population size is unknown, but most probably the population is smaller than that identified in the coastal forests to the north east of Bega."(p.17)* {Allen's subsequent 2011 work in the Northern part of Kooraban National Park suggested between 5 and 15 koalas active [4, op cit].}

For the whole Far South Coast Region, Allen reported:

> *"After assessing available evidence, Briggs (1999 - cit) estimated that koala numbers on the Far South Coast were between 100 and 1000 koalas, with numbers possibly being towards the lower end of this range.*
> *In rejecting a nomination to list the koala population in the study area as endangered the NSW Scientific Committee (2007 - cit) stated that satellite images indicate that, relative to the Koala's dispersal ability, suitable habitat for dispersal is largely continuous between the nominated population area and adjoining habitat, including forested land south to the Victorian border. Based on this habitat continuity and Wildlife Atlas records of Koalas, the nominated population is not disjunct from the broader population of Koalas that occupies forests in southeast NSW.*
> *The absence of anecdotal reports of koalas in recent years from any other part of the region, despite the high level of interest in the koala issue locally, suggests the assumption of a broader population of koalas may be optimistic. At best probably only a few breeding aggregates probably smaller in size than those estimated for the Bermagui/Mumbula population may be persisting.*
> *Eleven years after the Briggs (1999 - cit) estimate of koala numbers on the Far South*

Coast being between 100 and 1000 koalas, with numbers possibly being towards the lower end of this range the available evidence supports the lower estimate."(Pp. 17-18)

Koala behaviour

Substantial research exists on koala behaviour, especially in relation to browse species selection (see also ***Habitat***, below). Moore and Foley (2000) [64] provide a review, Hindell, Handasyde and Lee (1985 – 1988) [65; 66; 67] look at diet and eucalypt species selection, and Marsh, Wallis and Foley (2007) [68] study koalas' regulated intake of plant secondary metabolites. Matthews et al (2007) examine the effects of fire on resource use by a population of koalas in remnant coastal forest, for example:

> *Fifty-five koalas were monitored regularly by radio-tracking for up to 35 months. The attributes of each tree in which the koala was sighted were recorded, giving a total of 8,390 records. Analyses were undertaken on a range of ecological information. Regeneration of the forest began immediately following the fires and within three months koalas were seen among the epicormic growth. From a total 4,631 trees used by koalas, 3,247 (70%) were burnt. Observations of koalas feeding included 53% in burnt trees. Koalas changed trees frequently; individual trees were used once only on 3,555 occasions (42% of all observations). Of all the trees used, 95% were used by only one collared koala; no trees were used by more than three koalas. Swamp mahogany (Eucalyptus robusta) was the tree species most frequently used by koalas, particularly at night and by breeding females. Koalas preferred trees of larger diameter (>30 cm) and used significantly taller trees during summer.* {Abstract} [69]

Further reading includes *Sullivan et al, 2003* [70], *Clifton, 2010* [71], *Ullrey et al, 1981* [72], *Nagy & Martin, 1985* [73], *Ellis et al, 1995* [74], *Sliuter et al, 2001* [75], *Ellis et al, 2002* [76], *Tucker et al, 2008* [77], *Woodward et al, 2008* [78] and *Phillips et al, 2000* [79].

South East NSW research on patterns of koala preference for different trees and the nutritional values of each suggests size matters, diversity matters and varying the toxic load is essential (Allen (2010) [27, op cit]. Examples of the most visited in the Bega Valley Local Government Area (LGA) are Coast Grey Box (*Eucalyptus bosistoana*), Yellow Stringybark (*E. muelleriana*), Woollybutt (*E. longifolia*), White Stringybark (*E. globoidea*) and Red Ironbark (*E. tricarpa*). All of these occur in some mix or other in extant Eurobodalla forests, sometimes as one of the two dominant species in a patch with another species also used by koalas in the Bega Valley LGA eg Monkey Gum/Mountain Grey Gum (*E. cypellocarpa*), Silvertop Ash/Coast Ash (*E. sieberi*), Rough-barked Apple (*Angophora floribunda*), Blue-leaved Stringybark (*E. agglomerata*) and Black She-Oak (*Allocasuarina littoralis*). Other species occurring in the Eurobodalla (eg Forest Red Gum, *E. tereticornis*) and known as koala browse species elsewhere (Phillips, 2000 [80]), are also examined later as part of this pilot study's analysis.

A concise, up to date summary of the koala subject (including browse, range size and mobility) with special attention to the NSW South East is in Beissner (2012) [81]. For example, Beissner notes:

> *"Koalas generally move between different trees only a few times a day, but they still require a rather extensive home-range. The boundaries of these*

home-ranges vary according to location and habitat quality, and in the areas where they overlap, 'social trees' can be found. These trees are koala meeting places and essential to gene flow (TSSC, 2010; Allen et al., 2009; Ellis et al., 2009; Lassau et al., 2008; Martin & Handasyde, 1999), so it is easy to see how habitat fragmentation is detrimental to koala populations. Male koalas have a larger home-range than females, which could be attributed to the harem mating system (Allen, 2012; Allen et al., 2009; Ellis et al., 2009; Lassau et al., 2008). Many studies suggest that male and female koalas travel similar distances from natal to breeding home-ranges, ranging from approximately 3.5kms to 16kms (TSSC, 2010; Dique et al., 2004; White, 1999), but more current research indicates that it is usually the adolescent males that will travel further in order to find females to breed with and establish his own harem in previously unoccupied territory (Allen, 2012; SECRC, 2011)." (page 3)

<u>Habitat</u>
Later, this pilot study report asks whether existing classifications for <u>"core" and "potential" (or "intermediate" and "marginal") koala habitat</u> are obsolete at least for low density populations, because contemporary research since the Year 2000 now exists to justify at least querying one accepted view: that most of the Eurobodalla's forests no longer have viable carrying capacity according to these persisting descriptors.

The pilot project utilized many references in relation to habitat. Those addressing vegetation included Brooker and Kleinig (2006) [82], Costermans (2009) [83], the Forests NSW Field Guide (2005) [84], the Murramarang National Park extension research (1998) [85] and David Keith's survey of native vegetation (2004) [86]. Even anecdotal/historical remarks like that of Blay (1987) [56, op cit] were useful – Blay (*p.102*) referred to an intensive pre-1981 CSIRO vegetation type study of the Woila Creek area [volunteer researchers were still trying to find this reference at the time of editing this report], also mentioned by the South East Region National Parks Advisory Committee as having been considered as a translocation site. In respect of previous major disturbance, Blay mentions the 1953 Deua fire (*p.51*), the Big Badja/Woila fires circa 1968, another in the mid-1970s and the 1980 drought (*p.123*).

Other detailed data on flora and its specific areas of distribution, especially forest types, were consulted in the NSW Government's Terrestrial Biodiversity Tool [87], the Eurobodalla LGA Mapping Project (2000) [88], the Southern Rivers Catchment Management Authority (SRCMA) document on recognition and management of Endangered Ecological Communities (2006) [89] and the NSW Wilderness Red Index (1999) [90]. Connectivity is discussed by Mackey, Watson and Worboys (2010) [91]. In his work on tree species preferences, Phillips links to delineation of management areas for recovery planning (2000) [80, op cit]. The "Context Mapping" approach of Callaghan et al (2011) [92] might support the potential effectiveness and reliability of conclusions (and methods) being tested in this pilot study. Callaghan et al aimed to:

"determine key tree species for koalas in Noosa Shire (south-eastern Queensland, Australia) as a basis for mapping koala habitat quality. [They] applied a faecal-pellet survey methodology in 1996/97 to assess evidence of use by koalas of 4,031 trees from 96 randomly stratified survey sites across different eucalypt-forest and woodland communities. Results were compared

with those from a later survey undertaken in 2001/02 involving 5,535 trees from 195 sites that were distributed across broadly similar areas with the aim to investigate aspects of koala landscape ecology…..A total of 66.7% of the 1996/97 survey sites contained koala faecal pellets, recorded under 953 eucalypt trees (14 species) and 1,670 non-eucalypt trees (27 species). The proportion of trees at a given survey site that had koala faecal pellets at the base ranged from 2.2% to 94.7% (mean = 31.13_2.59% s.e.). For the 2001/02 dataset, koala pellets were found at 55.4% of sites, from 794 eucalypt and 2,240 non-eucalypt trees. The proportion of trees with pellets ranged from 3% to 80% (mean = 21.07_1.77% s.e.). Both the 1996/97 and 2001/02 surveys identified the same three tree species (forest red gum, Eucalyptus tereticornis, swamp mahogany, E. robusta, and tallowwood, E. microcorys) as the highest ranked for koala use in the study area. Three additional species (red mahogany, E. resinifera, small-fruited grey gum, E. propinqua, and grey ironbark, E. siderophloia) were identified in the 1996/97 surveys as key eucalypt species. Of the non-eucalypts in the 1996/97 dataset, coast cypress pine (Callitris columellaris) and broad-leaved paperbark (Melaleuca quinquenervia) ranked highest for use by koalas, followed by pink bloodwood (Corymbia intermedia) and brush box (Lophostemon confertus). White bottlebrush (Callistemon salignus), hard corkwood (Endiandra sieberi), M. quinquenervia and C. intermedia ranked highest in the 2001/02 dataset. The findings showed significantly greater use of larger eucalypts (i.e. 300-mm to >600-mm diameter at breast height)…..The identified key eucalypt species, being the critical limiting resource for koalas, were used to assign koala habitat-quality classes to mapped regional ecosystem types to create a Koala Habitat Atlas (KHA) for Noosa Shire. The combined two highest quality classes based on abundance of the key eucalypt species comprised only 15.7% of the total land area of the Shire…..The KHA approach provides a practical and repeatable method for developing koala habitat-suitability mapping for national, regional- and local-scale conservation and recovery planning purposes." (Abstract)

<u>Genetics</u>

Genetic issues associated with koala rehabilitation are important, as discussed for example by Cristescu et al (2009) [93] in their study of a bottleneck population exhibiting testicular abnormalities. Jurskis and Potter (1997) [52, op cit] offer a clear summary comparing "artificial" and "natural" populations in NSW, Victoria and Queensland at the time (*Pp. 41-42*). Lee et al (2010) [94] investigate koala populations in peri-urban Sydney, reporting:

"[The study] allows investigation of the impact of landscape features such as major roads and housing developments on koala gene flow…..Animals originating from four geographic sampling areas around Sydney, New South Wales, Australia, were examined to determine population structure and gene flow and to identify barriers to gene flow and management units. The….. study examined 12 microsatellite loci and used Bayesian assignment methods and genic frequency analysis methods to identify demographically separate populations and barriers to gene flow between those populations…..Three discrete populations were resolved, with all displaying moderate to high levels of genetic differentiation among them (q = 0.141–0.224). The allelic richness and heterozygosity of the Blue Mountains population (A = 6.46, HO = 0.66) is

> *comparable to the highest diversity found in any koala population previously investigated. However, considerably lower genetic diversity was found in the Campbelltown population (A = 3.17, HO = 0.49), which also displayed evidence of a recent population bottleneck (effective population size estimated at 16–21)…..Animals separated by a military reserve were identified as one population, suggesting that the reserve maintains gene flow within this population. By contrast, strong differentiation of two geographically close populations separated by several potential barriers to gene flow suggested these land-use features pose barriers to gene flow."* (Abstract)

Other works on breeding and genetics are *McLean & Handasyde, 2007* [95], *Ellis et al, 2002* [96], *Cocciolone & Timms* on DNA profiling *(1992)* [97], *Wilmer et al (1993)* [98], *Lee et al (2012)* [99] and *Tanaka et al (2009)* [100]. It was previously thought that koalas were comprised of 3 sub-species (management units - Southern, Northern & Central) but current research suggests these minor variations are a response to changes in environmental conditions and limited gene flow (*Melzer, 1995* [101]; *Takami et al, 1998* [102]; *Houlden et al, 1999* [103]), and that the differentiation between management units is currently too insignificant to conclude that there are sub-species of koala (*Houlden et al, 1999* [103, op cit]; *Melzer et al, 2000* [104]).

<u>Regulation</u>

Regulatory aspects are also relevant in terms of the prediction and eventual use of suitable habitat areas. These can be viewed in government publications such as the NSW Policy on Translocation (2001) [105] and the Regional Forest Agreement documentation [106; 107]. Masters et al (2004) explain how, in less than a century the ecological profile of koalas on Kangaroo Island has shifted from that of a species introduced for conservation purposes to one of pest status [108].

<u>Other locations</u>

There is also direct transferability to this pilot study of certain specialized literature on habitat, range and conservation methods in other comparable locations. The very recent (2011) *Biolink* draft Lismore report [109] challenges, at least in situ, previous assumptions about the influence of patch size, patch shape and connectivity as determining factors in a landscape's ability to support viable koala populations, such as the suggestion that the chance of koala presence declines once patches become smaller than 150 hectares. On the other hand, the authors observe that:

> "*While this is certainly not the case in Lismore…the survival of meta-populations (a group of sub-populations connected by dispersal) relies on the ability of animals to recolonise habitat patches where a sub-population has become locally extinct. Whilst habitat patches that are further apart are often considered less connected than patches close together, connectivity also depends upon the nature of the matrix and the existence of barriers to movement. The maintenance of habitat patches of sufficient size to support existing populations and provide for future population dynamics is fundamental to koala population and habitat management*". (*p.25*)

This aspect of the Lismore report relates to speculation about potential connectivity between the Eurobodalla LGA and adjacent LGAs (over a very large scale) as well as potential connectivities within the Eurobodalla (over smaller scales).

Other species of fauna
Baldwin's thesis on the Sea Eagle at Jervis Bay [110] shows how a native "mobile species" needs to be perceived, researched and conserved, and explores such aspects as the disconnection between Aboriginal and non-Aboriginal concepts of conservation (see *Methodology*). This latter, combined with discussions with University of Wollongong personnel working with Eurobodalla Aboriginal Elders on personal totems, was a key influence on the decision not to include Aboriginal heritage in the broader Eurobodalla Koalas project or this pilot study. The personal totems research was part of a Eurobodalla Shire Council project report about to be published on-line at the time of editing this pilot study report. Local Aboriginal people have access to the more sensitive aspects via a Council telephone number.

Statistical literature is relevant at three levels:

1. That which applies to the pilot study's overall conceptual model and method of analysis, at the level of interrogating the hypothesis, such as J. Michael Scott et al [11, op cit], more fully described in *Theoretical model* (p. 11 above).
2. That which applies to RGBSAT:
   Phillips and Callaghan (2000) [26, op cit] utilized confidence intervals from a data set comprising 14,313 trees from 405 field plots to assign threshold values for low, medium (normal) and high koala activity for three population density/habitat biomes in Eastern Australia. Their paper outlines the pooling of data sets and the derivation of confidence levels, and contains cautionary notes. An important advantage of RGBSAT over other survey techniques for this pilot study (see *Methodology*, p.30, above) was its production through the scat search datasheet of an intensive eucalypt type inventory at the localized plot level (ie 30 trees within a radius normally less than 30 metres for each plot – about one pixel for a *Landsat* image). Because the pilot study concentrated on potential habitat for koala revival, finding faecal pellets was less important than sampling eucalypt types and their distribution.
3. That which applies to mapping vegetation types:
   GIS operations can be used to consider spatial attributes and results from similar studies; then relate them to an hypothesis. When determining potential suitable habitat for any species it allows for easier visualisation of results whilst incorporating multiple influential factors (including slope and aspect if those layers are added) and providing values of likelihood, confidence and significance. Koala activity contour lines, suggested suitable habitat (including in areas that weren't RGBSAT surveyed), buffer zones and the connectivity between patches are generally calculated using statistical formulae to provide an accurate output.

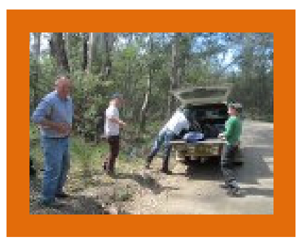
Shannon's Diversity Index might be applied to an analysis of koala-related eucalypt species richness and relative abundance (Tramer, 1969 [111]):

> "*It is suggested that the regulation of diversity by either the species richness or relative abundance components represent alternative strategies which are suited to predictable/nonrigorous and unpredictable/rigorous environments, respectively. Therefore, differences similar to those observed between birds and phytoplankton might be expected in other groups of organisms.*"
> {Abstract}

One input used by this pilot study to estimate the potential of Eurobodalla forests as habitat for a revived koala population was the cross-referencing of preferred browse species identified by surveys in the nearby Bermagui/Murrah district (known koala population – DECCW (2010) [27, op cit]), and from other research, with eucalypt species dominating forest types across the Eurobodalla. Welsh, Cunningham and Donnelly (2010) [112] undertook a detailed statistical analysis of koala habitat selection based on the plot data provided for the Bermagui/Murrah surveys and gave brief comment on other statistical analyses of these data. Their resulting general comments are cautionary:

> *"These analyses show some weak evidence of relationships between the probability of occupancy and several habitat variables. However the strength of the relationship is such that they are not that useful for prediction…Such models yield a parametrically smoothed map showing the spatial distribution of the target response in the study region, but do not produce similar maps for new regions."* (*p.9*)

In her examination of South East NSW habitat quality, Gow-Carey (2012) [54, op cit] used a G-test for Independence of strike rates and a statistical analysis of tree usage and availability, to derive a classification of tree species preferences. This was then applied spatially to model the extent of adequate habitat using the *Inverse Distance Weighted Interpolation* technique within *ArcMap10*. (*Pp. 33-53*)



Hypothesis

That the extant forests of the Eurobodalla will sustain a revived low density koala population if newly specified protected home range habitat and connectivity corridors for breeding are in place across the Shire.

<u>Rationale</u>
The pilot study was conducted in a politically charged context of contested viewpoints (ABC Online Discussion 2011 [113]), and an acknowledged paucity of local koala records and data (National Strategy 2009 [60, op cit]). Assumptions therefore needed to be treated with caution. Thus, the researchers began by developing an impression based on a combination of apparently transferable scientific and historical material from elsewhere in the New South Wales South East and Australia generally (CSIRO collection) [114], a meagre local historical record (Warry, 1990 [55, op cit] and <u>Blay</u>, 1987 [56, op cit], formal records of koala sightings (NSW Wildlife Atlas [59, op cit]), local knowledge gleaned from networking and unstructured oral interviews, preliminary examination of the literature [2, op cit, *Discussion Paper*, 2011, *pp.8-9*] as well as preliminary examination of earlier vegetation type maps available at the start of their inquiry (NPWS, 2000 [88, op cit]).

The impression was that prior to the full impact of Nineteenth Century European colonization (especially clearing for farming, probably hunting and the other early industries eg mining and pre-mechanised logging) a widespread low density koala population occurred across the Eurobodalla and nearby, with probable pockets of high density on the fertile alluvial river flats and in certain other "core habitat" zones. The impression was also that, as long as it was treated with due skepticism, an overall consistent but occasionally uneven pattern of decline, including some possible periods of relatively more rapid decline in the later decades, could be postulated for the Twentieth Century leading to a possible critical point for the localized koala population around the year 2000.

Preliminary examination of vegetation type maps from the Year 2000 (Shire-wide scale) [88, op cit; 115] and biodiversity and land use zone maps (smaller scale) (*Local Environment Plan, 2008 – 2011* [116]) seemed to suggest that extant forest offered potential broad landscape-scale linked low density habitat across nearly the length of the Shire in both a central swathe and a swathe forming an arc to the West, especially when State Forests, National Parks and some private land were viewed as a whole. There appeared to be three defined forest types in the central swathe, each of whose two dominant eucalypts were listed as amongst the preferred browse species in the results of surveys conducted at nearby Mumbulla (2010 [27, op cit]) and in earlier browse species research in Victoria (Hindell and Lee, 1987 – 1988 [65, op cit; 66, op cit], plus a discernible pattern of small pockets of remnant core habitat [117]. A second map (*Expert Agreed Habitat Model* [88, op cit]) suggested the existence of substantial connected "intermediate" habitat throughout the central Shire (South to North) in 2000.

It was postulated that:

- naturally revived or reintroduced koalas might feasibly adapt to these mainly intermediate level habitat extant Eurobodalla forests;

- assuming linked landscape-scale connectivity corridors are a feature of healthy systems (Mackie, Watson & Worboys, 2010 [91, op cit]) the koalas' absence might be an indicator of the forests' poor health; and,
- the animals' return would be an indicator of the forests' good health. (*In their discussion of the field of ecosystem ecology Chapin, Matson & Vitousek (2011) explicitly use this concept of habitat "health" [8, op cit].*)

Eurobodalla Shire Council biodiversity corridor maps (2009 – 2011 [116, op cit]) and Forests NSW compartment maps [118] consulted at the beginning of the pilot study appeared to suggest that existing protection zones were too small and were not connected (see home range and corridor sizes in *Definitions*, p.29 and *Suitable range areas and adequate connectivity corridors*, p.39, below) hence young or displaced koalas travelling from the home range in search of another breeding association would be unlikely to thrive.

It was concluded for the purposes of the pilot study that the post-colonial legacy of clearing and forest fragmentation precludes any future natural revival of a high density population anywhere in the Eurobodalla (*NSW Recovery Plan*, 2008 [61, op cit]). The reality for observers is that they will rarely if ever see a koala in low density circumstances, and numbers of resident or dispersing koalas usually have to be estimated from scat searches and other indirect evidence.

Definitions

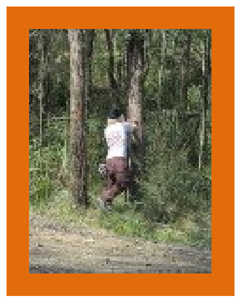
The hypothesis refers to "specified home range habitat and connectivity corridors for breeding". Based on the 2007–2009 Mumbulla surveys [27, op cit] a low density koala population typically constitutes "breeding associations" including a few breeding females, a dominant male and other associated koalas in home ranges of several hundred hectares of suitably large, healthy, mature and diverse eucalypt types (the researchers nominated explicit sites of interest for the RGBSAT surveys). The dominant male is believed to eject competitors and young koalas are thought to leave their mothers' home ranges at about age two years.

It was postulated safe connectivity corridors for dispersal and/or breeding would probably be between 0.5 to 1 kilometer wide at least, with protection from predators and vehicle impact and protection of the complexity of the ecological mosaic, and might need to link home ranges from relatively small distances apart to up to fifty kilometres apart. This thinking was based on the limited material available early in the pilot study. These aspects are more precisely examined in the 2011 Lismore draft report [109, op cit] and other materials consulted by the pilot study after it began (see *Suitable range areas and adequate connectivity corridors*, p.39, below).

Null hypothesis

The hypothesis is a positive construct from the conservationist perspective, hence devices were required to control for researcher bias as much as possible. Amongst the contested viewpoints, for example, was the counter-argument that remnant forests contain mainly marginal habitat and that, while insufficient data exist to confirm localized extinction, the numbers would be so low that it is not cost-effective to search for or try to enhance protections for koalas in areas like State Forests; rather, the most cost-effective conservation strategy is to encourage private landholders to rehabilitate their alluvial river flats. This viewpoint was expressed in tandem with the assertion that the Comprehensive Regional Assessments ensured Forests and National Parks were appropriately placed for wildlife protection, and the Threatened Species Licence provisions [33, op cit] under the Regional Forest Agreement [106, op cit] were adequate [119; 120].

The null hypothesis (H_0) was therefore kept in mind at all stages of analysis, when results were compiled and when conclusions were drawn. The null hypothesis implied that:
The extant forests of the Eurobodalla will <u>not</u> sustain a revived low density koala population whether or not protected home range habitat and connectivity corridors for breeding are newly specified.



Methodology

Put simply, the methodology was:

1) to prepare a multi-layered GIS map using the most contemporary available data sets, and interpret these to display areas of potential home range and connectivity corridor habitat;
2) to undertake 21 sample plot surveys in the field, using the RGBSAT technique;
3) to cross-reference these two elements in the light of contemporary literature. (see *GIS*, below, and *Appendices 2 and 3*).

This is not unlike the methods used by Hammond (1997) [17, op cit] for his predictive habitat work immediately to the Eurobodalla's north. Hammond used fuzzy sets to deal with uncertainty in a modeled process that incorporated such devices as image rectification of remote sensing data sets. (*Chapter 4, Pp. 40-55*)

To aid the cross-referencing exercise and in an attempt to control for error, the three overlapping fuzzy sets and the two simple tests suggested by Scott et al (2002 [11, op cit]), described in *Literature Review* and *Appendix 1*, were applied once the GIS map was complete and the survey data structured as an attribute table.

Although an effort was made to undertake some basic research of the more comprehensive collection of relevant methodological detail (see referencing in *Literature Review* and *Hypothesis* (above), it was clear the pilot study could not practically (and its personnel were not qualified to) implement such sophisticated models and statistical procedures. The methodology was therefore kept simple, in keeping with:

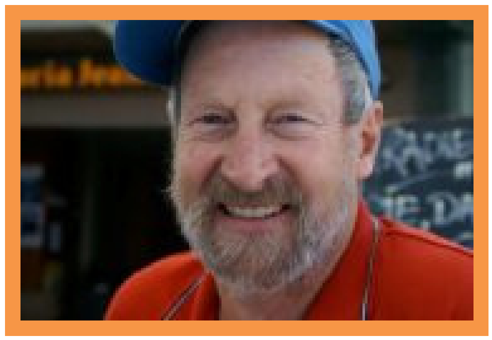
- the minimal resources available to the project;
- the inexperience of the volunteer researchers in this subject area;
- the implementation of the pilot study as a way of learning about the geographic and theoretical fields;
- the implementation of the pilot study as a way of exploring appropriate research techniques; and,
- the use of the pilot study to prepare the way for any future studies of a larger or more intensive type - described in a February 2012 research funding application as follows:

  > *"The subsequent larger phase of research would include a comprehensive survey requiring three years' work by a large group of fieldworkers, and the refinement of the GIS map into a more sophisticated product. The post-2012 activity might include establishment of an "LTER" (long-term site based field research centre) in the Eurobodalla by the University of Canberra."* [121]

Geographic Information Systems (GIS) mapping analysis

The volunteer project was helped in this aspect by Southern Rivers Catchment Management Authority (SRCMA) Batemans Bay office, NSW Office of Environment and Heritage (OEH) Narooma office and the Australian Koala Foundation.

Project volunteers utilized *ArcGIS10.1* to display and interpret the relationship between vegetation type maps for the Eurobodalla, literature on koala habitat (especially browse species, home range size and connectivity) and the data obtained from the sample of RGBSAT plot surveys.



The first priority was to overlay the plot survey points on the vegetation-type map, convert eucalypt type plot data into an attribute table, match these to the detailed floristic descriptions for each polygon in the vegetation type layer, then view the resulting patterns in the light of findings from the literature.

The purpose was to see if

(a) this simple model would allow preliminary conclusions to be drawn about whether the Eurobodalla appears still to have adequate home range habitat and connectivity to support or disprove the hypothesis (ie that a revived low-density koala population could be sustained) and/or,

(b) this basic method of analysis appears to have the capacity for development into a more sophisticated model using larger data inputs (eg the results of a comprehensive survey effort) and the wider scope of *ArcGIS* (eg complex model-building, regression analysis and the further application of software extensions like *Spatial Analyst*).

The second priority, time permitting, was to incorporate additional layers such as slope, aspect and land use zones. Ultimately the 2012 pilot study did not have time to incorporate slope and aspect, but was able to add a layer displaying the boundaries of National Parks and State Forests in the Eurobodalla.

In summary, the practical questions the pilot project asked its GIS component to help answer were:

1. *Do we have viable home ranges for low density koala populations in the Eurobodalla (in terms of range size and adequacy of the mix and density of browse species and any other factors)?*
2. *Do we have connectivity between these ranges to allow for breeding behaviour?*

3. *Is there connectivity with known koala populations in adjacent Shires?*
4. *What features of our Eurobodalla landscape, land use zones, tenures etc are potential enhancers or inhibitors of low density koala revival?*
5. *What would need to be done to implement a koala recovery strategy?*
6. *If the GIS model can't answer these questions yet, how would it need to be further developed to do so?*

Analysis

In considering its value for future research, it is worthwhile comparing the process outlined below with that mentioned in *Statistical literature* (above), where Gow-Carey [54, op cit] spatially applied her G-test and statistical analysis of tree usage and availability, to derive a classification of tree species preferences to model the extent of adequate habitat using the *Inverse Distance Weighted Interpolation* technique within *ArcMap10*. (*Pp. 33-53*)

The Eurobodalla Koalas project pilot study of 2012, however used twenty-one sources (cited in *Appendix 2*) of information on how intensively different eucalypt species appear to be used relative to one another by low density koala populations. In the light of this literature, species likely to occur in the Eurobodalla were categorized for their probable contribution to the necessary mix for viable habitat. The categories were called “Primary”, “Secondary”, “Supplementary” and “Suspected”. Species were allocated to this hierarchy by virtue of the relative importance attributed to them by the cited sources.

These categorized species were then plotted against the detailed positive diagnostic floristic descriptions accompanying the GIS vegetation type map – the *SENSW_SCIVI_2230* [122]. The *Southern Forests_CRA_FE_P_3859* [123] map was also available, but time constraints precluded its use in a parallel analysis. (The maps’ floristic descriptions contained additional species not mentioned by the sources. These species might also require future checking for their suitability, namely *E. paniculata*, Grey Ironbark, *E. fibrosa*, Broad-leaved Red Ironbark, *E. gummifera*, Red Bloodwood and *E. piperita*, Sydney Peppermint.)

This plotting exercise enabled conclusions to be drawn about which forest types (represented as polygons in the map, and therefore able to be viewed for their potential range size and connectivity) might provide viable habitat for low density koala populations (based on eucalypt type and relative frequency of occurrence only – other habitat parameters such as tree size, slope, aspect, proximity to water source, disturbance, microclimate and weather history were reserved for later analysis as resources permit, as part of a larger future study). *Appendix 4* summarises the results, whereby 6 vegetation type polygons were classed as offering potentially high quality habitat, 19 medium, 53 low and the remaining 113 nil. *Appendix 5* (*“Habitat potential” file*) displays the result as a broad scale Shire-wide map.

This was purely an exploratory exercise. The allocation of classifications to polygons was based on a reading only of the mix and frequency of occurrence within the polygons’ floristic descriptors, of eucalypt types from *Appendix 2*. For full validity the exercise would need to be repeated using a statistical control (see *Suggested further research*, p.67 below).

The detailed cross referencing of SCIVI vegetation type polygons with the pilot study's RGBSAT field plot data is in the table at *Appendix 3*, *Sheet 2* {"*Plot Spp summy (2)*"}. This material was produced for use in the application of the fuzzy sets and theoretical accuracy tests (see *Theoretical model*, above, *Application of the tests*, below and *Appendix 1*).

A start was made using polygons from the OEH CRA map in relation to the plots surveyed in Autumn, but time precluded their use with the Spring plots, so the derived broad scale map (*Appendix 5*) and the theoretical tests used only the SCIVI map polygons and their floristic descriptors.

A "plot/polygon compatibility range" was generated; that is, a range of levels to rate the apparent correlation between the RGBSAT plot data and the SCIVI vegetation type polygon in which the plot was situated. This was drawn from a reading of the frequency of occurrence of multiple eucalypt types in the relevant SCIVI polygon (and where the plot sat close to the boundary, the adjacent polygon) and their relative importance in the browse mix as shown in *Appendix 2*. Seven levels were described as follows:

1. Polygon floristic descriptor confirmed by the RGBSAT plot ground proofing
2. Polygon content and plot data reasonably compatible
3. Correlation for "Primary" species (only) was found
4. Polygon and overall plot data partially compatible
5. Adjacent vegetation type polygon required to generate compatibility
6. Virtually no correlation
7. No correlation

A range representing decisions on potentially how suitable the eucalypts in each RGBSAT plot might be as browse mix for low density koalas also produced seven levels. Note the conclusion in *Appendix 2* from reading the 21 sources: that koalas in low density circumstances seem to need a mix of at least two "Primary" species and perhaps up to three others (eg "Secondary" and "Supplementary"). The levels were:

1. Potentially very good
2. Potentially good
3. Potentially fairly good
4. Potentially modestly useful
5. Requires adjacent forest type for suitability
6. Only the "Supplementary" species show potential
7. Insufficient diversity of suitable eucalypt types

Finally, a range with six levels summarized the apparent habitat potential when eucalypt types and frequency in both the RGBSAT plot data and the SCIVI polygon were viewed together:

1. Very good
2. Good
3. Fairly good
4. The plot and polygon require help from the adjacent polygon to generate suitability
5. Only "Supplementary" species show potential
6. No good

Dusky Coral Pea – Merricumbene
(photo – Candace Wirth)

Regularised Grid Based Spot Assessment Technique (RGBSAT) scat searches and vegetation validation

This aspect was the subject of an application for a Forests NSW *Special Purpose Permit for Research* (not forthcoming by the time of this report's editing), and collaboration with the National Parks and Wildlife Service including registration of some Eurobodalla Koalas project volunteers as authorised NPWS volunteers. Plot data obtained by the volunteer project were shared with these agencies as well as Eurobodalla Shire Council, the University of Canberra and Southern Rivers Catchment Management Authority.

As mentioned previously, RGBSAT was chosen by this pilot study as its preferred device for ground-proofing 21 selected sites relevant to the study's use of landscape-scale Geographic Information Systems (GIS) vegetation type, habitat and connectivity corridors maps. The total number of plots surveyed was dictated by the time and funds available to volunteers.

Of these, ten (10) plots were surveyed at Tinpot, a location fairly close to the successful 2011 Kooraban/Gulaga 72-plot survey in the Bega Valley Local Government Area (LGA) [4, op cit]. The intention was to start checking northward continuity of browse species and koala activity on National Park, State Forest and private tenures.

The remaining eleven (11) other locations were chosen for their potential to test the suitability of extant vegetation in the light of

(a) historical records and local sightings of koala presence, or
(b) their positioning in terms of apparent habitat or vegetation type and future connectivity across the Shire, as well as the potential for connectivity to known populations in other adjacent LGAs, ie Cooma-Monaro, Palerang and Shoalhaven.

The eleven non-Tinpot locations were at: Gulph Creek above Nerrigundah; Cadgee; Big Belimbla Creek; Turlinjah/Moruya-West on Dwyers Creek Road; Buckenbowra Road West of Mogo; Runnyford Road near Mundarlow Creek; "*The Lagoon*" near Merricumbene; and, Donovans Creek and Old Store Roads near East Lynne.

The surveys were conducted during Autumn and early Spring (March to May 2012 and September to October 2012). *Sheets 3 onwards* in *Appendix 3* comprise the 21 completed data sheets.

Although RGBSAT is about the presence/absence of koala faecal pellets (Phillips and Callaghan, 2000 [26, op cit]), significantly for this proposed seeding project's predictive habitat model, the plot surveys double as an on-ground intensive inventory of eucalypt species and their sizes (measured in diameter at breast height – DBH). This was one of the reasons other easily implemented field survey techniques (eg the "transect" method used by Forests NSW) were not preferred. Also, indications were that actually discovering scats was very unlikely.

Another reason was that RGBSAT appeared to offer greatest potential for statistical control and interrogation because of its "regularised grid based" features. It was considered the RGBSAT method eliminates a degree of bias when sampling species that have a low density distribution.

A plot is selected at, or as near as practicable to the intersection of the grid lines on the standard 1:25,000 topographic map, permitting clear data entry and back-referencing (retrospective inquiry) as well as the capacity for surveying a grid of adjacent related plots at a scale of 1:1,000 metres (and smaller controlled scales if required) hence providing systematic coverage of broader areas.

The regularised field datasheet and results database allow for future large-scale work to be built upon existing data, ie producing an ongoing updatable system. The datasheet also contains fields for multiple additional plot data that might be critical to assessments of habitat suitability (see below). Gow-Carey's work [(2012) 54, op cit] is one example of what extra can be done with the RGBSAT data post-survey.

A practical reason for the choice of method was that the South East's NPWS koala survey specialist used RGBSAT. His mentoring and expertise were available to the pilot project, within his time constraints.

Under RGBSAT, at each plot site a large tree at the grid intersection (or if the 1000 metre grid intersection is impossible an accessible alternative, eg the 500 metre point) is chosen as the centre tree, and its GPS coordinates recorded. The survey team then moves outward from the central tree in a clockwise direction, until a total of thirty (30) live trees of any species with diameter breast height (DBH) of 150 millimetres or more, have been found in order, numbered in the datasheet and marked with ribbon. An intensive search of litter is conducted under each tree covering a radius of one metre from the base. Numerous entries are made in the datasheet for each plot, later to be entered on the database. Each tree is recorded for its number (ie space-relationship to central tree) species and DBH. Other entries include

- site number,
- name of data recorder in the field,
- post-field data entry information (who entered, who checked and when),
- time and date of survey,
- site tenure,
- GPS coordinates (Easting, Northing, Datum and GPS Error),
- geology (granitic, metasediment or basalt),
- soil depth,
- soil type (sandy, sandy loam or loam),
- aspect (in which direction the slope of the plot faces),
- plot radius,
- SAT criteria (reason for search: koala seen, pellets seen or scheduled grid plot),
- groundcover and ease of searching (easy, moderate, hard),
- whether or not a koala is found in any tree,
- whether or not koala faecal pellets are found under any tree,
- age of pellets,
- percentage of pellets-to-trees in the plot,

- evidence (scats, digs, mounds, nests, calls) of other fauna having used the plot,
- any scats found during the informal "transect" exercise while walking to and from the plot,
- names of survey team members,
- any other comments.

Additional relevant post-survey data such as height above sea level, weather patterns, fire history, logging history, farming history and mining history can be gleaned from topographic maps and agency records.

As described in *GIS - Analysis* above, for the purposes of checking the research model and cross-referencing survey findings to the broad scale GIS map layers, eucalypt species from the completed Excel datasheets were used to populate an "attribute table" for point data on the GIS map and subsequent analysis. This GIS sub-model was prepared by working backwards from the study requirements to the detail of fields in the attribute table's design, to give the best possible options for analysis in the light of the study's questions and purpose.

Cross referencing the methodological elements

Application of the fuzzy sets

As indicated in *Theoretical Model* (above), application of three overlapping fuzzy sets was recommended by Scott et al [11, op cit] as the first of two theoretical tests to check for error in studies of this kind.

Acknowledging the need for (a) the derived GIS map layers and (b) the process for deciding upon survey plot-to-map polygon floristic consistencies to be repeated within a proper statistical control in a future full study, those developed in the 2012 pilot study were applied according to the fuzzy set formula as follows.

Intersection=min{A,B,C} where:
A = the layers (of High, Medium, Low and Nil potential habitat) produced in the derived GIS map (*Appendices 4 and 5*)
B = the consistency of these layers' floristic descriptors with their associated RGBSAT plot survey results (*Appendix 3*, *Sheet 2*)
C = any scats or records of koala presence found in relation to the eucalypt types inventory within each RGBSAT survey plot or vegetation type polygon (*Appendix 3*, *Sheets 3ff*).

When the three intersecting fuzzy sets were applied schematically (*Appendix 1*, *Sheet 1*) serious inconsistency was present between the two tables (see full discussion in *Pilot Study Results*, p.58 below), suggesting potential theoretical error. This needs to be taken into account when drawing conclusions about the validity of the theoretical model or its processes.

Application of the tests

The second set of theoretical checks suggested by Scott et al ("accuracy tests") involved graphing convergence of map and survey results for suitability values against the hypothesis (while also keeping the null hypothesis in mind), thereby:

1. assessing potential habitat rather than forecasting actual abundance or occurrence of the species; and
2. assessing the degree to which the model of potential habitat overestimates the potential for the species to occupy the geographical area.

First, the map-based potential habitat ratings predicted by reference to the SCIVI polygon floristic descriptors, as compared with the 21 sources on low density koala habitat, were graphed. Second, the decisions about the potential of polygons after they were ground-proofed by the RGBSAT plots were graphed. The results are in *Appendix 1*, *Sheet 2*, and illustrate a totally positive finding. In contrast to the concern about inconsistency shown by application of the fuzzy sets formula, this exercise appears to support the hypothesis, and to indicate the potential of the habitat was in fact strongly underestimated by the initial map-based predictions.

Suitable range areas and adequate connectivity corridors

The logic of the hypothesis incorporates the caveat that newly specified protected home range habitat and connectivity corridors for breeding would need to be in place across the Shire. It was necessary, therefore, for the pilot study to pay attention to what constitutes a suitable home range, what constitutes an adequate connectivity corridor for breeding, and whether extant Eurobodalla forests still contain (or could feasibly contain) these.

<u>Classifying habitat</u>
How "potential habitat" is classified, especially in the light of newer knowledge about browse species for low density koala populations, is a critical aspect of the Eurobodalla Koalas predictive habitat approach.

Hammond (1997) [17, op cit] demonstrates knowledge of the time in a clear conceptual model for a GIS-based prediction of "<u>high-quality</u> potential habitat", wherein "quality habitat…would most likely have a distribution where the climate is within a critical range for both the animal and the key elements of its habitat". Hammond lists these critical elements (with source references) as:

- the nutrient status of areas is fertile above a critical limit (*Braithwaite et al, 1983*)
- topography is most likely less than 20 degrees slope (*Norton and Neave, 1996*)
- the habitat area supports a drier forest community (*Jurskis et al, 1994*)
- the tree species in the habitat area are from a limited range producing necessary leaf nutrition and low toxicity (*E. viminalis and E. tereticornis* were nominated) (*Lee and Martin, 1988; Norton and Moore, 1991)*
- the tree species are within a suitable distance from a viable water source (*Norton and Neave, 1996)*
- the habitat areas are those that have experienced the least amount of disturbance (*Reed and Lunney, 1990*)

(*p.17*)

As mentioned in *<u>Literature Review</u>*, the CRA exercise (Gellie (1998) [18, op cit]) appears to underpin official classifications of the viability of South East NSW koala habitat to this day, but as mentioned in *<u>Local History</u>*, Gellie's report indicates no suitable model was found for the koala. The vegetation type maps available to the CRA modelling exercise were of vintage Year 1996 (a decade prior to the SCIVI map available to this pilot study, itself now potentially too old). Gellie et al used the "KBS" (Keith et al), the CSIRO "120 unit" and the CSIRO "20 class", as well as the NPWS Eastern Bushlands Database.

It needs to be acknowledged that the CRA exercise was as thorough as time and other resources permitted. Its sophisticated mathematical modelling, attention to mammal habitat factors other than browse species, and involvement of expert advisers remain impressive. Contextual landscape variables (eg percentage of old growth within a one kilometre radius; percentage of clearing within one or two kilometres) are examples of the kinds of inputs. Abiotic variables were digital elevation, mean annual rainfall, mean annual temperature, ruggedness, topographic position etc, all generating indices derived through complex formulae. Prediction values were assigned from the "variable classes dataframe" and imported into *ArcView Spatial Analyst* and used to spatially interpolate a map of predicted species distribution. The output was three maps; of "predicted", "upper" and "lower" confidence limits. So, Gellie et al produced a digital map with values indicating the probability of occurrence of a species, and a postscript file containing information about the model. References were provided for the theory and mathematical detail, as well as the software used in the modelling.

On the other hand, potential shortcomings of the CRA exercise from the point of view of this pilot study included:

- the grouping of all mammals together when running them through the modelling as a batch (species separation for modelling purposes was constrained by lack of time and funds);
- the most important file for running a batch was the "sites" file, which treated presence of species and absence of species separately (*Arcview Spatial Analyst* then produced "pseudo-absences" for "presence-only modelling" (*p.24*) – for the koala the process produced 390 records in presence-only modelling, 13 presence-absence records, and no suitable model;
- the use of opinions as the input from the expert panels;
- no time to run statistical cross-validation or to conduct field validation, so acceptance of the models was based on the experts' evaluation – stakeholders with vested interests had input.

The significance of the CRA work for the issues raised in this pilot study can be found amongst Gellie's conclusions, eg:

- the study demonstrated the important role for predictive modelling in regional conservation evaluation and planning;
- lack of records to enable modelling for a large number of important species;
- acknowledgement of disputes amongst stakeholders and experts, through differences in personal/professional opinions and perceptions;
- the need for more time to refine and statistically cross-validate, and to undertake validation in the field.

The more recent work on browse patterns and eucalypt species in specific locations (see *GIS*, p.31 above and *Appendices 2 and 3*), is fundamental to the proposition that low density populations can adapt to (and potentially revive in) what has previously been thought of as "intermediate" or "marginal" habitat. In May 2012 the issue of standardizing koala habitat classification was raised in the context of implementing the new Commonwealth Biodiversity Fund projects in the Bega Valley region. Until then official documentation referred to koala habitat as "core", "intermediate" or "marginal". Alternatively references were made to "core" and "potential" habitat. (See *Appendix 2*, *NSW Recovery Plan*, 2008 [61, op cit].) In essence, "core" habitat was where koalas are present and "intermediate" habitat was where what have previously been considered as the right trees, are present. "Primary", "secondary" and "supplementary" species listed in the Recovery Plan were from work done up to the Year 2000; probably Gellie et al (1998) [18, op cit] as mentioned above. The species listed for the South Coast were:

Primary food tree species:

Cabbage gum *E. amplifolia,* Forest red gum *E. tereticornis,* Ribbon gum *E. viminalis*

Secondary food tree species:
Yellow box *E. melliodora,* Woollybutt *E. longifolia,* Brittle gum *E. mannifera,* Maiden's gum *E. maidenii,* Yertchuk *E. consideniana,* Snow gum *E. pauciflora,* Swamp gum *E. ovata,* Red box *E. polyanthemos,* Large-fruited red mahogany *E. scias,* Coast grey box *E. bosistoana,* Apple-topped box *E. bridgesiana,* Blue box *E. baueriana,* Monkey gum *E. cypellocarpa,* Bastard eurabbie *E. pseudoglobulus*
Stringybarks/supplementary species:
White stringybark *E. globoidea,* Brown stringybark *E. capitellata,* Yellow stringybark *E. muelleriana,* Southern white stringybark *E. yangoura,* Blue-leaved stringybark *E. agglomerata, E. baxteri*

These Primary and Secondary species, but not the Stringybarks (Supplementary species) are replicated unchanged in the Koala prescription for the *Draft Private Native Forestry (PNF) Code of Practice (Southern NSW)* public consultation paper (2012) [124]. In mid-2012 Southern Rivers Catchment Management Authority organized public meetings seeking input from stakeholders on the NSW Government's plan to revise the Native Vegetation Regulation 2005 (which pertains to clearing etc) and the PNF code "to cut red tape and remove inconsistencies, while still maintaining or improving environmental outcomes" {*Fact Sheet 7*}. The draft was accompanied by a discussion paper – *Review of the Native Vegetation Regulation: Private Native Forestry and Koalas* [125]. The discussion paper summarises the status of the koala in NSW, the measures in the current Code of Practice to protect koalas, State Environment Planning Policy 44, the use of vegetation mapping to guide Koala Plans of Management (KPOMs), and the use of alternative definitions of koala habitat considered to be more locally accurate and relevant than "potential", by Coffs Harbour City Council, Port Stephens Council, Kempsey Council and Lismore Council. The discussion paper raises questions about vegetation and habitat mapping, including the scale, quality and accuracy of the regional mapping and models, the nature and scale of certain map types, the amount of field validation, the age of the imagery used as a basis for mapping (a challenge faced directly by this pilot study – see *Further Improving the Method*, p.63 below), and whether procedures could be put into place to improve the validation of mapping at an individual property scale. The relevance of types of mapping (eg habitat quality –vs- distribution/abundance), how potential but unoccupied habitat should be treated, differences in habitat classification among local government areas, and cost, are all canvassed. Three options are suggested: (a) no change (continuation of the current rules); (b) PNF prohibited in certain mapping categories of an approved KPOM and restricted in other categories; and, (c) certain mapping categories in an approved KPOM trigger on-ground validation before prohibitions and prescriptions are applied if koala habitat is found to be present.

At the heart of integrating current and future mapping with the regulation of PNF is precisely the question of what constitutes suitable habitat addressed by this pilot study, especially in relation to the potential adaptation of low density koala populations to habitat previously deemed non-core. This pilot study and any follow-up research might inform the decision making, and might generate a Eurobodalla case study for the NSW Government's review processes.

Although comprehensive, and perhaps because they also seem to overlap somewhat with those in the Shoalhaven, Victorian border and Monaro districts, the *Recovery Plan* classifications do not match browse patterns found in Chris Allen's 2007–2009 surveys of Bega Valley habitat [27, op cit]. As mentioned previously, the strongest correlates with the presence of koala pellets in Allen's Mumbulla survey were:

> Coast grey box (*Eucalyptus bosistoana*), Yellow stringybark (*E. muelleriana*), Woollybutt (*E. longifolia*), White stringybark (*E. globoidea*), and Red ironbark (*E. tricarpa)*

Others in the Mumbulla survey found to be associated with koala activity were:

> Monkey gum/Mountain grey gum (*E. cypellocarpa*), Silvertop ash/Coast ash (*E. sieberi*), Rough-barked apple (*Angophora floribunda*), Blue-leaved stringybark (*E. agglomerata*), and Black she-oak (*Allocasuarina littoralis*)

Gow-Carey (2012) [54, op cit] addresses these matters directly, finding there is a large proportion of adequate habitat across the South East NSW coastal region surveyed by Allen and his teams between 2007 and 2011. Gow-Carey found the trees being utilized differ substantially from those listed as primary feed trees in the region and suggests that localized assessment of habitat requirements is needed to create informed plans of management. She provides a comparison of the classification of trees in her study with those outlined in the NSW Recovery Plan, as follows (*p.80*):

Species	Gow-Carey's results	Recovery Plan classification
E longifolia	Primary	Secondary
E cypellocarpa	Primary	Secondary
E tricarpa	Primary	-
E bosistoana	Secondary	Secondary
E globoidea	Secondary	Supplementary
E muelleriana	Secondary	Supplementary

So, Gow-Carey remarked (*p.80*) "It can be hypothesized that there may be unique adaptations that koalas in this region have made to exist as a stable low-density population. It has been thought that this endemic population may have a unique ability to forage an existence in this 'marginal' country by having unique genes and an inherited knowledge of country and place."

Gow-Carey goes on to say "The study area has long been thought to be of low to moderate habitat quality due to the poor soils and absence of 'primary' feed trees, implying habitat is only suitable for supporting a low density koala population (Braithwaite 1983 *cit*; Lunney & Leary 1988 *cit*; Phillips 2000 *cit*). However, considering the [*role of nutrients and toxicity*] results of Stalenberg (2010) [126] in light of the findings of this thesis reveals that habitat quality across the region may well be equal with other areas supporting higher density koala populations. This suggests that there may be other historical land use patterns that have limited the distribution of koalas." (*p.81*)

In his unpublished notes for a NSW OEH/Department of Planning meeting at the time, Allen cited a 2011 paper by Phillips proposing a four-tiered system of habitat classification [127], as well as his own Southern Tablelands research, to explore the notion that low-density populations exhibiting "low activity" levels appear to be browsing successfully on a previously inadequately understood mix of eucalypt species. Allen noted that Southern Tablelands koala activity appears to be more likely, and activity levels appear to be higher, where there is a diversity of "secondary" and "supplementary" species, and that his surveys showed *E. viminalis* appeared to be functioning as a "secondary" rather than "primary" browse species, and *E. rossii*, which is not listed in the NSW Recovery Plan, appears to be either a "secondary" or "supplementary" browse species. It was suggested local factors such as browse species availability, topography, microclimate, disturbance history, size-class and regrowth rates are perhaps more important. {*This is consistent with the view expressed informally by a Eurobodalla Koalas project associate experienced in looking after koalas in captivity; that "they'll eat anything", especially at the right time of year, including their enthusiasm for E. maculata, Spotted Gum (not present in scat survey results) in October to December, and the potential for Spotted Gum to provide Winter "tipping". The project also has an anecdotal record of koalas having once been seen using Spotted Gum at Bermagui. In addition Jurskis and Potter [52, op cit] mention a radio-collared koala living in Spotted Gum forest at Bermagui – see below. As shown in* <u>*Appendix 2*</u>*, Sheet 1, Hammond [17, op cit] and Williams [128] cite E. maculata as a species used by koalas.*} Allen recommended greater flexibility where "activity contour delineation" is used to develop new definitions.

That browse species not used by koalas (or indeed found) in the Bermagui/Mumbulla and Kooraban/Gulaga areas are used by koalas elsewhere in Australia, further suggests that traditional notions of what constitutes "a koala tree" (eg the legendary status of *E. tereticornis*, often cited in the vernacular, to the exclusion of others) might be faulty.

The 2011 *Biolink* Lismore report [109, op cit] discusses new knowledge about koala habitat:

> *"The identification of preferred tree species across large and heterogenous landscapes can be a complex process, as it is now recognised that a number of factors influence the way koalas utilise their preferred suite of eucalypts, including the extent of habitat fragmentation, historical disturbance, stochastic events such as fire, and the nutrient status of the soil (Moore and Foley 2000; Phillips and Callaghan 2000; McAlpine et al. 2006). Knowledge regarding habitat use by koalas – and most importantly the issue of preferred food trees - has grown substantively over the last 10 – 15 years. Earlier studies by Phillips and Callaghan (1995), followed by Harris (1999) and independent observations by koala carers made important contributions to local knowledge, collectively isolating key food tree species such as Forest Red Gum Eucalyptus tereticornis, Tallowwood E. microcorys, and Swamp Mahogany E. robusta.*
>
> *Largely as a component of broad-scale habitat sampling undertaken for purposes of the AKF's Koala Habitat Atlas, a review of koala food tree preferences across NSW was initiated by the NSW Koala Recovery Team in 2000. This work (Phillips 200b) presented an overview of koala food tree preferences throughout the species range in NSW, while also – for the first time – providing a mathematical basis for the classification of preferred koala food tree species as Primary, Secondary or Supplementary. Associated work by Phillips et al (2000) and Phillips and Callaghan (2000) further demonstrated that high levels of use of some tree species could be positively associated with their proximity to preferred food trees, and that underlying*

soil landscape could also influence food tree palatability such that even broadly accepted food tree species would be preferred on one soil landscape but avoided on another. Ongoing biochemical studies of this phenomenon (e.g. Moore and Foley 2005) have confirmed such volatility to be more widespread than previously known, and that it is particularly prominent in the Eucalyptus sub-genera Symphomyrtus (Gleadow et al. 2008)." (p.20)

The issue of variety in diet also required testing by the pilot study, in terms of availability. Forest types are usually summarised in map legends using two dominant eucalypt types, and the Eurobodalla surveys tended to show heavy dominance of one or two species in each plot. Some koala surveys elsewhere indicate heavy reliance on two types (eg the surprisingly bleak Numeralla Gum Reserve location - *E. mannifera* and *E. smithii* although pellets were also found under *Allocasuarina littoralis* and some *E. viminalis*). The Bermagui/Mumbulla evidence on the other hand shows five species strongly correlated with koala activity and a further five associated with koala activity. The sources used for *Appendix 2*, taken together tended to suggest two "primary" species and three "Supplementary", "Secondary" or other species are the minimum requirement for a viable diet across a koala's range.

The survey findings for Eden reported by Jurskis and Potter in 1997 [52, op cit] show why meticulous care is required in examining the browse species issue from a predictive habitat perspective. Contrary to Allen's Mumbulla results, Jurskis and Potter (*p. 23*) did not find koalas using Red Ironbark *E. tricarpa* (a species that also occurred in this pilot study's plot surveys at Tinpot, prompting speculation that it might be part of a suitable browse mix in the Eurobodalla). Their report for one set of sites at Eden was:

"*E. cypellocarpa was clearly a preferred species and being reasonably common, was a very important species (White and Kunst 1990) to koalas. E. maidenii was also preferred but was less common and therefore less important. Although the data suggested that E. sieberi was not preferred, it was frequently used and common so that it was important (White and Kunst 1990) to the koalas in escarpment forests. E.fastigata was infrequently used by koalas.*"

Their report for a second set of sites at Murrah was:

"*The limited data suggested that E. consideniana - yertchuk and E. longifolia - woollybutt were preferred and important species (White and Kunst 1990) for koalas in the Murrah area. E. sieberi was not necessarily preferred but was frequently used. Some stringybarks and Angophora floribunda - rough-barked apple were occasionally used by koalas. Corymbia gummifera bloodwood did not seem to be an important species for koalas in that area.*"

Note the findings for example, for one of the radio collared koalas ("Ruth"):

"*This koala did not use tree species and size classes in proportion to their availability (0=206.60, 35df, p <0.01). It was infrequently observed in 'sapling sized' trees (smaller than 30 cm dbh) even though these were the most common trees in its range. The koala preferred trees of E. cypellocarpa in all size classes above 30 cm dbh. The koala preferred (G=126.58, 11df, p<0.001) trees with crown class 4 or 9 (Florence 1996, Appendix 6) which are trees suffering substantial competition or having crowns distorted by past competition.*" (*p. 27*)

Tree preference results varied noticeably amongst individual koalas. Another interesting result is the Bermagui example cited above:

> "*The radio-collared koala at Bermagui lived in forest dominated by spotted gum (Corymbia maculata). E. muelleriana and E. cypellocarpa were prominent associates. This koala often roosted in rainforest trees (32% of observations), most commonly grey myrtle (Backhousia myrtifolia). It seemed to shelter in the rainforest during unfavourable weather (high temperature, strong winds or heavy rain) (A. Cotterill, State Forests of New South Wales, pers. comm.).*"

Further suggesting koalas will adapt to a large variety of browse species, on 24th July 2011 researchers attended Birdland Wildlife Park (Batemans Bay) to view feeding time for the park's two captive koalas, *Boris* and *Macca*, and to interview the Head Keeper, Karen Best. Karen showed how the koalas seek out the tips, because they're after the moisture ("koala" – Aboriginal word for "no drink"). She mentioned Messmate, a Southern NSW species (*E. obliqua*) as a particular favourite, as well as Tallowwood, a Northern NSW tree (*E. microcorys*) and Blue Gum, a Tasmanian tree used in mainland plantations (*E. globulus*). Karen explained that "the Birdland boys" (*Boris & Macca*) "will eat 22 of the 80+ Australian eucalyptus species" (*cf* the separate practitioner's remark cited earlier: *"they'll eat anything"*). Birdland has about 2000 small trees in its on-site plantations, on drip-feed with timers, fertilised every two months. Karen said it's difficult because the soil is sandy loam and needs a lot of water, whereas the soil on Karen's property at home (Donovans Creek Road, East Lynne) from which she also obtains feed, is better – clayey and hard. The trees in the Birdland plantations are:

- Swamp Mahogany/Swamp Messmate (*E. robusta*)
- Yellow Stringybark (*E. muelleriana*)
- Forest Red Gum (*E. tereticornis*)
- Sydney Blue Gum (*E. saligna*)
- Southern Blue Gum (*E. globulus*)
- Manna Gum (*E. viminalis*)
- Grey Gum (probably *E. punctata*)
- Tallowwood (*E. microcorys*)
- Silvertop Ash (*E. sieberi*)
- Swamp Gum (*E. ovata*)

Naturally occurring species Karen said she brings in from home for the koalas are:

- Messmate (*E. obliqua*)
- Yellow Stringybark (*E. muelleriana*)
- Red Stringybark – not strictly a coastal tree (*E. macrorhyncha*)
- Sydney Blue Gum (*E. saligna*)
- A Red Gum Karen called "*chameljanensis*" which she described as being like Manna Gum/Ribbon Gum (may have meant *E. camaldulensis*, but normally in this area *E. tereticornis* would be the expected Red Gum)
- River Red Gum (*E. camaldulensis*) (Karen said she and her sister have alluvial river flats and it grows on them, but again the expected Red Gum in the Eurobodalla would be *E. tereticornis*)

Species Karen said she has planted at home (she has tube stock) are:

- "Silverton" ("Red Gum") – unknown to researcher

- Swamp Mahogany (*E. robusta*)
- Manna Gum (*E. viminalis*)
- Tallowwood (*E. microcorys*)

<u>Home range size</u>
The mapped results for radio collared koalas reported by Jurskis and Potter, led them to the following conclusion on this aspect:

> "*The average home range size (HM) was 169 ha equivalent to an average density of .006 koalas per ha of Forest.*" (*p.40*)

In reporting her 2011 undergraduate project, Merinda Williams [128, op cit] includes figures (and her sources cited below, *Williams Pp. 33-37*) to summarise known home range size. Williams' own study reports a spotlight survey which detected 25 koalas (including four of these with young) within the campus grounds, indicating a population density of 0.625 individuals per hectare. Williams remarks "*This value is within the expected range for koala abundance within fragmented habitat in the Northern Rivers region of New South Wales, and is consistent with a previous study conducted within the Lismore area {Gall, 1980 cit – one animal per hectare}.*" Other material cited by Williams gives an idea of the great variety of findings but also suggests the Bega Valley and Southern Tablelands density figures found by Allen [below] might be a reasonable rule of thumb for the Eurobodalla:

- McAlpine et al, 2006; Rhodes et al, 2006 – "*The average home range is dependent on the number of trees per unit area. This usually extends to an area anywhere within the span of 1–200 ha.*"
- Mitchell, 1990 and Melzer et al, 2000 – "*larger home ranges (and therefore lower koala densities) occurred in areas where preferred tree species were more sparsely distributed.*"
- Ellis et al, 2002 (Central Queensland) – "*the home range was estimated as being between 101-135 ha*."
- Hindell and Lee, 1987 (Brisbane Ranges/French Island); Martin & Handasyde, 1999 – "*the home range for males was greater than that of females, at 3.1 ha and 2.1 ha respectively" and "supported by a range of studies that home ranges for male individuals is up to double that of females*" and "*a measure of abundance is provided by the calculation of koala population densities*."
- Hindell and Lee, 1987 (Central-West Victoria) – "*a density that fluctuated between 0.7 – 1.6 animals per hectare was reported, and abundance levels more than eight animals per hectare in north-eastern Victoria*."
- Mitchell, in Martin and Handasyde, 1999 – "*densities of 6-9 animals per hectare have been documented on French Island, Victoria*."
- Mitchell and Martin, 1990 in Dique et al, 2004 – "*densities as low as 0.005 koalas per hectare have been suggested*."
- McAlpine et al, 2008 – "*koalas select individual tree species and forest stands with preferred tree species of a high proportion within their home range*."
- Dique et al, 2003; McAlpine et al, 2006 – "*even though the koala is a solitary species, the home ranges of males and females will generally tend to overlap when home ranges are extensive*."

Chris Allen's Bermagui/Murrah surveys (2007-2009 [27, op cit] produced the following observation:

"*An occupancy rate of 11.21% in a study area of 21,000 ha suggests that approximately 2354 ha of the area is occupied by koalas. With home range areas of 50–100 ha, a population of 23–47 koalas is suggested. This is only a tentative estimate, with some factors suggesting a higher estimate is warranted (for example, koalas will have overlapping home ranges and there may be unidentified activity cells) and others that it should be smaller (for example, the area derived using the occupancy rate data overall may be larger than home range areas).*"

Allen's 2011 Kooraban/Gulaga survey report [4, op cit] remarks:

"*These results suggest that only 5-15 koalas are surviving in the approximately 7000 hectares of forests assessed in this survey*" and "*The low activity levels at the active sites also suggest that the individual home ranges are large. As is the case with the Bermagui-Mumbulla population, each resident koala is probably occupying between 50 and 100 hectares with minimal overlap."* (p.13)

Allen's earlier submission to the Threatened Species Scientific Committee (2010 [24, op cit]) contained the following:

> **"***Jurskis and Potter (1997, cit) provide data on home range areas used by radio-tracked koalas in the region. The harmonic mean areas of four mature koalas that appeared to be resident animals averaged 82ha. Supporting this, in assessing the data gathered in the preliminary phase of the 2007-9 survey in the Coastal Forests to the north east of Bega, Biolink (2007, cit) concluded that the koala home range areas within the study area were 50 -100 ha.*
> *In the 2007-9 survey, 17670 trees at 589 sites covering a study area of approximately 22000 ha were assessed. Koala pellets were located at 66 (11.21%) of these sites. From these data we can extrapolate an overall "occupancy rate" (Phillips et al 2007, cit; Biolink 2007, cit) of approximately 10%, with this rate increasing to approximately 20% in Mumbulla State Forest, to the south of the study area, an area of approximately 6,000 ha. {Note that data from Campelltown (Ward and Close, 2004 cit) and from Kempsey (Phillips, pers. comm.) for low density populations of koalas utilising gum/stringybark eucalypt communities indicates koalas utilising smaller home range areas (10 – 20 ha and 30 ha respectively). It is possible that the home range size estimates above are conservative and in fact are somewhat smaller.}" (p.16)*

In their 2000 document arguing the advantages of the RGBSAT survey technique [26, op cit] Phillips and Callaghan make the following observations about range size:

> *"Studies of free-ranging Koalas have established that those in a stable breeding aggregation 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 (ie several years) fidelity to the home range area is generally maintained by adult Koalas in a stable population (Mitchell 1990; Phillips unpub. data)." (p.3)*

…and:

> *"Ideally, activity levels derived from SAT sites should only be interpreted in the context of location-specific habitat utilisation data (Lunney et al. 1998;*

Phillips et al. 2000; Phillips and Callaghan 2000). Low activity levels recorded in what might otherwise be considered important Koala habitat may be a result of historical disturbances including logging, mining, fire frequency, agricultural activities and/or urban development. Such considerations should not necessarily detract from the potential importance of such habitat for longer-term Koala conservation, particularly if Koala food trees are present and Koalas are known to occur in the general area.
Low activity levels can also be associated with low-density Koala populations. Stable, low-density Koala populations are a natural phenomena in some areas (Melzer and Lamb 1994; Jurskis and Potter 1997; Phillips and Callaghan 2000). Koala density 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). 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 tend to be both size-class and/or density dependent when compared to a primary food tree species (size-class and/or density independent) (Phillips et al 2000; Phillips and Callaghan 2000). Application of a "Koala Habitat Atlas" type methodology over the larger area in conjunction with historical research (eg Knott et al 1998) would be useful to clarify such issues." (p.7)

The authors include a table showing:

"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 has been pooled to reflect three major categories of Koala activity which correspond to low and med-high density Koala populations of the tablelands and areas east of the Great Dividing Range, and those of more western areas respectively. Koala densities for the low density category are arbitrarily defined at ≤ 0.1 Koalas/ha." (Data sources cited.) (p.13)

Gow-Carey's (2012) study of the Tanja/Bermagui/Mumbulla/Kooraban/Gulaga low-density habitat [54, op cit] included class analysis revealing proportions of each mapped habitat class (*p.66*) as well as mean patch size (*p.67*) and patch size variability {smallest and largest patches for each suitable category} (*p.68*). For example:

- 14,001 hectares of "highly suitable" habitat represented 33.6% of the total and 17,938 ha of "suitable" habitat represented 43% of the total;
- the mean patch size for "highly suitable" habitat was 138.6 ha, for "suitable" 118.8 ha, for "marginal" 96.2 ha and for "not suitable" 33.0 ha; and
- there were large variations between smallest and largest patches for each suitable category, eg the smallest "highly suitable" patch was 76 m^2 and the largest patch was 27,340,933 m^2.

The 2011 *Biolink* report for Lismore [109, op cit] does not specifically analyse range size, but in its analysis of the history and reasons for varying occupancy rates, provides the following commentary:

"Habitat fragmentation can also be a contributing factor to population decline and/or dissolution. Recent research by McAlpine et al. (2005; 2006; 2007) into the landscape ecology requirements of koalas suggests that the

chances of koalas being present declined rapidly as the percentage of koala habitat or overall forest cover fell below 60-70% of the landscape. There was also some evidence of critical patch size requirements for koalas, with koalas more likely to be absent from patches of primary and secondary habitat that were less than 50ha in size, while the probability of koala presence started to decline below a habitat patch size of around 150ha (McAlpine et al. 2007)." (p.4)

…and:

"An inherent problem associated with survey data such as historical records is that they are essentially observer-biased and do not represent the results of a systematic survey effort. Hence, quantitative range parameters such as the Extent of Occurrence (EoO), the related Area of Occupancy (AoO), and concepts such as generational persistence can potentially miscalculate the full extent of change (positive or negative) and/or the locations of such things as source populations respectively if existing bias' cannot be accommodated…" (p.5)

Connectivity corridors

In 1997 Jurskis and Potter [52, op cit] reported on radio collared koalas:

"*The female koala 'Roberta' made a long foray (over 3 km) for a short period during summer. This may have been a mating event. A female has been recorded moving 2.6 km out of its range to mate, presumably in response to male bellows (Lee and Martin 1988, Lee et al. 1990). Long forays outside their home ranges were observed for each of the two sub-adult males. These koalas may have been in search of breeding opportunities. The 'forays' occurred in winter ('Wayne') and spring ('Bob'). The mature male 'Robert' ventured well outside its HM 90% home range during summer but the home range was based on a limited number of observations. Koalas mate in spring and summer according to Lee and Martin (1988). Some of the observed forays may have been related to mating or attempts to secure mating opportunities*." (*p.48*)

In the Senate Estimates hearings of 22nd May 2012 on the Environment portfolio, Mr Sullivan (for the Government) remarked:

"…recent research was released I think last week out of researchers Dr Bill Ellis and his colleagues at the University of Queensland looking at koalas. They have a longstanding research program with respect to koalas. They released a scientific paper last week which said that 50 per cent of koala pregnancies come from travelling males. That is completely different from where we thought that was in terms of that percentage in years gone by where we were focusing on habitat connectivity for resident groups of koalas. This shows the importance of having connectivity for the koalas that can roam the landscape. So, that comes down to that evolutionary connectivity, where we are adding new genes to the gene pool, all the way through to the corridors that the koalas need to move between habitat zones.

So, in terms of the objectives of corridors, it is really about protecting, maintaining and restoring those habitats I just talked about, protecting and enhancing resilience and at the same time supporting both local, regional and in some cases international movement of species." [129]

On connectivity corridors, the Lismore report [109, op cit] concludes:

> *"An ability to move freely across the landscape allows for the effective dispersal of subadult koalas between breeding populations. On a broader scale such movements facilitate wider dispersal and so maintain genetic diversity, and can lead to re-establishment of populations where they may have died out. In the Lismore area local habitat links include riparian vegetation along Tucki Tucki and Marom Creeks and the Richmond and Wilsons Rivers, open space zones on the Northern Ridges, Goonellabah and East Lismore which connect larger remnants, and remnant vegetation between Invercauld and Rous Roads and between Military Road and Invercauld Road. Southern Cross University land, both the main campus area and the Technology Park site also form important habitat areas and linkages, as do Weston Park/Caroona Nursing Home/Goonellabah Primary School, across to the Northern Ridges area.*
>
> *The influence of patch size, patch shape and level of connectivity are supposedly key factors determining the ability of a landscape to support viable koala populations….The maintenance of habitat patches of sufficient size to support existing populations and provide for future population dynamics is fundamental to koala population and habitat management. To this end a three-faceted approach will be required, consisting of the following foci.*
>
> *1. Retention of koala habitat in-situ in the first instance, with a focus on occupied habitat, and adjoining areas of potential koala habitat.*
>
> *2. Protection of bushland areas that contain preferred food tree species is also necessary to preserve the habitat resource.*
>
> *3. Maintenance and creation of vegetated linkages between habitat patches and source populations.*
>
> *4. Strategic revegetation work with the aim of consolidation of existing habitat patches and habitat creation. Revegetation work should focus primarily on "gapfilling" in large habitat blocks within and adjacent to mapped source populations, edges of habitat blocks and within linkage areas." (Pp.25-26)*

Mackey, Watson & Worboys (2010 [91, op cit]) reviewed the scientific basis for the connectivity conservation approach that underpins the Great Eastern Ranges corridor. Their report has a planning policy orientation with an advocacy flavor, but includes remarks that relate to the themes of this pilot study, and is instructive in terms of definitions, eg:

> *"Any discussion of connectivity invariably leads to consideration of 'corridors'. As with 'connectivity', there is a diverse range of meanings used by conservation researchers and practitioners (Chester and Hilty 2009). As noted by Anderson and Jenkins (2006), at the most basic level, **linear corridors** (which establish or maintain relatively straight-line connections between larger habitat blocks and extend over distances of up to tens of kilometres) can be distinguished from **landscape corridors** (that maintain or establish multidirectional connections over entire landscapes and can encompass up to thousands of square kilometres). **Linear corridors** will usually be one of the structural elements in a **landscape corridor** initiative. Anderson and Jenkins (2006) also identified the following ways in which the term 'corridor' is used in conservation:*

__biodiversity corridors__ (also called __biological corridors__) – large-scale landscape linkages covering hundreds to thousands of square kilometres – the term is therefore synonymous with __landscape corridor__

__corridor networks__ – systems of corridors running in multiple directions

__dispersal corridors__ – corridors that promote the movements or migrations of specific species or groups of species; synonyms include __movement corridors__ and __wildlife corridors__

__ecological corridors__ – corridors that maintain or restore ecological services on which biodiversity conservation depends (this term is unfortunately alternatively used as a synonym for 'biodiversity corridor')

__habitat corridors__ – linear strips of native habitat linking two larger blocks of the same habitat.

Presumably, the purpose of __corridor networks__ and __habitat corridors__ is complementary to those of __dispersal corridors__ and __ecological corridors__.

In summary:

(a) landscape corridors (and their synonyms, __biodiversity__ or __biological corridors__) describe the principal geographical component of a connectivity conservation initiative

(b) elements of a landscape corridor include __dispersal corridors__ (such as __corridor networks__ and __habitat corridors__) and __ecological corridors__ (which focus on landscape permeability for ecosystem processes).

Bennett and Mulongoy (2006) made the useful distinction between:

__linear corridors__ such as a hedgerow, forest strip or river

__stepping stones__ or arrays of small patches of habitat that individuals use during movement for shelter, feeding and resting

__interlinked landscape matrices__, which comprise various forms that allow individuals to survive during movement between habitat patches.

Again, these three types of corridor are possible structural elements of a landscape corridor.

A complementary categorisation of corridors was provided by Bennett (2003), based on their origin:

__disturbance habitat corridors__ – including roads, railway lines, cleared utility lines, and other linear disturbances

__natural habitat corridors__ – including streams and riparian zones typically following topographic or environmental contours

__planted habitat corridors__ – including farm plantations, windbreaks and shelterbelts, hedgerows and urban greenbelts established by humans

__remnant habitat corridors__ – including roadside woodlands ('beauty strips'), linear stretches of unlogged forest within clearcuts, and undisturbed habitats between protected areas

__regenerated habitat corridors__ – formerly cleared or disturbed linear strips where vegetation has regrown, such as 'fencerows' and 'hedges'." (p.20)

Mackey, Watson and Worboys also address:

> *"the question of __scale__. The various ecological and evolutionary processes referred to [sic] operate at different spatial and temporal scales. This fact has been long recognised (Allen and Starr 1982) but only more recently factored into conservation thinking (Soulé et al 2004). The scales at which a selection of ecological and evolutionary processes occurs is illustrated [Figure]. Many significant processes operate at trans-bioregional scales, encompassing biome*

level, and continental and biogeographic realm (Udvardy 1975) scales. Systematic conservation planning therefore needs to identify strategies and prescriptions at multiple scales, and identify processes that impact on and 'connect' locations beyond any single landscape, bioregion or State boundary. This is true even for fine-scaled processes operating at more local scales such as pollination, nutrient flux and the maintenance of ecologically functional populations in a landscape. Attention to fine-scaled processes might be required if they are affected by processes operating at larger (bioregional, biome and continental) scales (Sanderson et al 2006)." (p.13)

The writers explore:

- *"the structural configuration of habitats or habitat patches in a landscape mosaic*
- *the permeability of a landscape mosaic for dispersal and movement of a specific species*
- *the presence or absence of barriers or impediments to the natural flux of water, nutrients, or fire experienced in a landscape*
- *landscape permeability with respect to meta-population dynamics*
- *gene flows associated with micro and macroevolutionary processes." (p.12)*

Amongst many other planning–related observations, Mackey, Watson and Worboys conclude:

"The best response to the threats of habitat loss and degradation is to retain natural lands in an undisturbed condition. The second most important response is to retain strategic interconnections to make habitat remnants both bigger and less isolated. However, habitat rehabilitation strategies still need to consider conservation management in the broader landscape matrix. Management of the land surrounding remnant habitat patches can also be critical for some threatened species in the fragmented landscapes of eastern Australia, for a number of reasons. It can contain habitat and resources for species with specific needs or large territories that cannot otherwise be found in the remnant patches. In addition, it can be a movement conduit for some species, thus reducing the negative effects of habitat isolation. When the matrix is not managed to meet the needs of species it can become simply too hostile for native species to survive and these landscapes experience higher extinction rates in habitat fragments than in more appropriately managed landscapes.

Australia's native species have used various life history strategies and responses to persist through past climate change events such as local adaptation, long distance dispersal and range contraction to refuges. However, the problem is that climate change overlays a suite of other serious human-caused threatening processes – especially habitat loss, fragmentation and degradation; the introduction of feral animals and invasive plants; and changed fire and hydrological regimes. These threatening processes are interfering with the natural adaptation processes that enabled species to persist through previous climate change events. Ecologically interconnected and intact natural lands maximise the opportunities for species to positively respond to climate change. The GER corridor provides an opportunity for coordinated, large scale responses to the challenges of climate change…..Connectivity conservation provides a conceptual framework for *breaking free from minimalist thinking that risks locking protected areas into an ever-tightening extinction vortex…..Connectivity conservation and its effective management provide an opportunity for a fresh look at land use and the long-term needs of biodiversity conservation." (Pp.6-8)*

In March 2012, the *Draft National Wildlife Corridors Plan* [130] (containing numerous relevant references, national and regional maps) was presented to Minister Burke. Accompanied by a photograph of a koala using a purpose-built road underpass, the draft remarked:

"*Corridors in peri-urban and urban landscapes*
Our urban and peri-urban areas are moderately or highly engineered landscapes, and are particularly concentrated along Australia's coastlines. Nevertheless, some peri-urban areas do retain substantial natural areas at their fringes. In recent times, many urban planners and developers have been more mindful of environmental needs when designing urban areas. Zoning and planning that supports connectivity conservation can protect watercourses and important habitat, and keep valuable ecosystems healthy and resilient. Urban and peri-urban wildlife corridors, which can flow between towns, suburbs, parks and reserve lands can raise community awareness and actively engage a diversity of community in conservation and management activities." (*p.20*)

Blanket acceptance of the importance of corridors for koalas is unwise, however. Prevett (1991) [131] studied the mobility of koalas and their use of disturbed habitats varying from natural remnant eucalypt forest to planted residential areas and *Pinus radiata* plantations in a "largely human-dominated landscape" (Ballarat's urban-rural fringes). A comparison was made between the movement paths and patterns of vegetation usage by translocated and non-translocated koalas using radio telemetry tracking. Prevett's summary concludes:

"Koalas were able to cross large tracts of open and alienated land. Success in crossing these spaces suggests that continuous tracts of habitat in the form of vegetation corridors are not essential for koala movement. Any stress induced by long distance movements in short periods of time may be exacerbated by contact with dogs." (*p.259*)

If Prevett's findings for Ballarat were to be replicated in the wider forests of the Eurobodalla, they might support the notion that, even if the GIS polygons containing apparently suitable habitat for low density koalas are separated by others that are apparently unsuitable, this need not preclude the wider landscape from being considered capable of supporting a population. Gow-Carey's (2012 [54, op cit] mapping exercise appears to support this phenomenon for the known populations she considered in the region immediately south of the Eurobodalla.

Prevett says "The movement path taken by a koala may be influenced by several factors. Those factors most likely involved include distribution and selection of suitable browse species, social interactions and various forms of disturbance." (*p. 267*). "In this study, evidence was presented which showed that koalas made extensive use of vegetation remnants and have the capacity to move between remnants and cross areas of open land. There was, however, little evidence to suggest that koalas use continuous corridors of vegetation as conduits. Where blocks of native forest abutted exotic pine plantations, both translocated and non-translocated koalas passed directly from the native into the exotic vegetation. Directional movements were maintained in these plantations until they had passed through and out the other side." (*p. 270*) "Koalas were found to make extensive use of trees on private land including residential areas, institutional land and farmland." (*p. 270*) "Koalas were shown to use solitary senescent trees on farmland to form links between patches of vegetation." (*p. 271*) "The major finding when the movement paths of translocated and non-translocated koalas are compared is that the paths taken by translocated koalas [*they were translocated from other places in the same district as part of the local conservation management strategy*] all showed strong directional components which resulted in each koala moving a considerable distance from the release tree. Thus *K017T* moved at least 5km, *K137T* 9km and *K160T* 10.6km during the study. In contrast, non-translocated koalas showed localized movements and after a period of several months were within 2-300m of their capture point." (*p. 268*)

White (1999) [132] also found that corridors are not necessary for koalas. White:

> *"investigated home-range size, utilisation of tree species and patches, and the influence of spacing behaviour by females on social organisation. It was undertaken in south-east Queensland in an area dominated by agricultural activity (beef and dairy cattle and cropping). Extensive clearing in the study area resulted in patches of vegetation that varied in size from less than 1 ha to blocks of 50–100 ha. Eucalyptus tereticornis and E. crebra were the dominant species in these patches and koalas used both species. The average home-range size (delineated by the 95% probability polygon from a kernel estimator) was 34.4 ha and 15.0 ha for males and females respectively; that delineated by the 70% probability polygon was 12.5 ha and 5.0 ha for males and females respectively. Koalas were not reliant on corridor systems and sometimes moved further than 5 km in a season. Koalas have few non-food-related requirements, i.e. they do not need den sites, nest sites, display areas, etc. Furthermore, they do not utilise the understorey and their mobility between patches does not appear to be compromised by the absence of corridors of trees. It is suggested that, in comparison with other arboreal marsupials, it should be relatively easy to provide habitat for koalas within rural areas."* (Abstract)

The opposite seems to be suggested by Beier and Noss (1998) [133] who, one year earlier than White, wrote about species in general:

> *"Skeptics have questioned the empirical evidence that corridors provide landscape connectivity. Some also have suggested dangers of corridors. We reviewed published studies that empirically addressed whether corridors enhance or diminish the population viability of species in habitat patches connected by corridors….Fewer than half of the 32 studies we reviewed provided persuasive data regarding the utility of corridors; other studies were inconclusive, largely due to design flaws. The evidence from well-designed studies suggests that corridors are valuable conservation tools. Those who would destroy the last remnants of natural connectivity should bear the burden of proving that corridor destruction will not harm target populations."* (Abstract)

Scotts (2003) [25, op cit] reports in detail on the NPWS Key Habitats and Corridors (KHC) Project for North East NSW, an important modeling reference:

"The Key Habitats and Corridors (KHC) Project aims to inform [conservation] programs, and offer a basis for integration, by developing a regional landscape conservation framework.
The KHC Project refines the systematic consideration of fauna, as a conservation focus, across the landscape through the summary and integration of modelled distributions of priority forest species, and their application as conservation planning surrogates for biodiversity and ecological processes. With the aid of innovative Geographic Information System (GIS) analysis tools, key habitats and linking corridors for priority faunal assemblages are delineated across north-east New South Wales (NSW). The mapped outputs provide the only spatially complete, data-driven, and systematically derived synthesis of a conservation planning framework for the region. They form an explicit basis for regional protected area networks and provide a landscape context for conservation programs. As predicted high conservation-value habitats, the mapped key habitats and corridors are also focus areas for the protection, enhancement and restoration of native vegetation…..
The GIS-referenced key habitats and corridors maps have been submitted to regional conservation programs in north-east NSW (such as regional Vegetation Management and Water Management Committees, Catchment Management Boards, and regional and local government environmental planning). The NSW National Parks and Wildlife Service (NPWS) has initiated a communication strategy to promote the mapping and its application; the products are also being prepared for posting on the internet. The key habitats and corridors approach has been applied in trials outside north-east NSW, and is currently under consideration for detailed application in areas of eastern NSW where suitable data sets of the modelled distributions of species are available." (Summary)
and
"Overall opinion is heavily weighted in favour of a significant role for corridors in regional conservation planning and management (for reviews see Bennett 1990, 1998; Noss et al. 1997). Habitat connectivity is a feature of natural environments and the available evidence indicates that corridors provide habitat and connectivity benefits in many instances (Beier & Noss 1998), assuming that they are of suitable size and shape, habitat type and that they connect areas of substantial habitat value (Lindenmayer 1998; Perault & Lomolino 2000). Corridors are deemed to represent a particularly important subset of overall connectivity, and a part of the wider landscape matrix, where conservation efforts may be focused in order to maintain, or enhance, regional conservation potential." (p.23)
and
"…..distributional information relating to certain elements of the north-east NSW biota has been expanded and improved over the last decade through several large-scale field surveys and data collation projects, and the development of an extensive biological databases (NPWS 1994a,b, 1995a,b, 1999a,b; Ferrier et al. 2001a; Hines & Brown 2001). Vertebrate fauna and vascular plants were targeted in the development of the biological database, with some work undertaken on invertebrates (Gray & Cassis 1994). This was coupled with the concomitant development and refinement of an

environmental database and a predictive modelling capacity operating within the framework of a GIS (Ferrier 1991; NPWS 1994c; Ferrier et al. 2001b). The predictive distributional models for species of forest fauna were derived by Generalised Additive Modelling (GAM) of biological survey data in relation to mapped environmental variables (Fig. 2.2). For each modelled species, the probability of occurrence was spatially interpolated by applying the fitted GAM to environmental GIS data for every 100 metre × 100 metre grid cell within the study area, yielding a continuous probability of occurrence surface (NPWS 1994a, 1999a)." (Pp. 32-33)
and
"Width of corridors
***Note:** 1. Minimum benchmark corridor widths are not always attained in the final refined corridor polygons. This may be the result of a variety of factors including the area, configuration and type of extant vegetation available, the nature of the local topography, and presence of other features, such as towns and roads and the like. 2. Minimum benchmark corridor widths may be exceeded for assemblage reference species with small home-ranges in order to maintain overall consistency for regional corridors (minimum of 500 m) and sub-regional corridors (minimum of 300 m). 3. More than one assemblage reference species is chosen for certain assemblages (see Table 6.2) because some are restricted to only a subset of a KHC Project analysis area, even though representative of the assemblage within the area occupied." (p. 56)*

Bennett (2003) [134] defines and describes linkages in detail (including concepts of corridors and stepping stones), and explains their advantages and disadvantages for wildlife and conservation. {Of note because of its co-occupancy of koala-suited habitat (and the fact that the Greater Glider uses Eurobodalla forests), Bennett observes "*the Greater Glider is a solitary folivorous marsupial that occupies a home range of 1–2ha…*"}

The *Biolink* Coomera-Pimpama Report (2007) [135] contains some figures on range and corridor size:

"Approximately 70% of the C-PKHA's koala population is currently residing within the designated Urban Koala Area (UKA), the extent and configuration of which suggests that it functions as the major source population for the C-PKHA…..
In order to retain at least the Minimum Viable Population (MVP) of 170 koalas within the C-PKHA long term, a large and virtually unroaded habitat patch approximating 1500ha in size will need to be established within a relatively short period of time (10 – 15 years)." (Executive Summary)
and
"Bushland areas that contain Eucalypts within the C-PKHA currently cover a total area of only 1716ha, the balance comprising mainly cleared lands with isolated trees and small patches of native vegetation. The preferred koala food trees within the C-PKHA are Tallowwood E. microcorys, Forest Red Gum E. tereticornis, Swamp Mahogany E. robusta and Grey Gum E. propinqua. The greater proportion of bushland (1035ha) occurs within the boundaries of the UKA, with that remaining in the KCA (681ha) mostly disjunct, remnant bushland patches." (p.7)
and

"Koala densities within the C-PKHA average 0.23 animals/hectare overall, but are highest within the designated "redline" areas (i.e. areas supporting resident koala populations), wherein the average density is 0.30 koalas/ha (range: 0.24 – 0.33 koalas/ha). Extrapolation of this density data suggests a maximum carrying capacity for the C-PKHA at this point in time of approximately 674 koalas." (p.7)

and

"Factors that we believe have contributed to the current population size estimate include a relatively long inter-fire period, the extent and distribution of koala habitat within the C-PKHA generally, and the fact that the majority of koala habitat currently exists in a largely rural residential setting with low traffic flow, all of which suggest that incidental harvest due to motor vehicle strike and dog attack [3%] is currently at sustainable levels [<6%]." (p.7)

and

"Currently, 681ha of remnant bushland containing eucalypts exists outside of the UKA (i.e. within the designated KCA), of which 244ha (35.8%) is already occupied by resident koala populations (approximately 154 koalas). In contrast to those of the UKA however, redline areas (i.e. koala meta-population cells) within the KCA are small (mean size = 29.1ha, range 0.7 – 141.8ha), disjunct and widely distributed, consistent with their having stemmed from the larger source population(s) resident in the UKA." (p.12)

Narrow Leaf Geebung (Persoonia linearis) Changing to black after they have fallen-skin of fruit unpalatable but pulp ok - research has shown some geebungs have anti-bacterial properties and the bark was used by Aborigines to tan fishing lines

(photo – Candace Wirth)

Pilot Study Results

Method

Generally, the method proved straightforward to implement. Its theoretical base and theoretical construct were accepted by participants and peer review readers. The methodology permitted a simple GIS model to be constructed, that can accept inputs from prior research, new analysis of existing data, or from field surveys. The GIS model can produce derived polygons in a map representing the results of analysing these inputs. The map can accept additional layers for the purposes of display or further analysis. The GIS model can cater for multiple habitat factors in addition to eucalypt type. The GIS model appears as though it will accept and benefit from future statistical controls over inputs that can be applied to enhance validity. This basic method does appear to have the capacity for development into a more sophisticated model using larger data inputs. The RGBSAT survey component appeared to function as a worthwhile ground-proofing mechanism.

Nature of the low density browse mix

Appendices 2 and 4 contain these details. The number of eucalypt species potentially forming a viable browse mix for an adapting potential low density koala population in the Eurobodalla appears quite large. The patterns amongst this mix and the relative importance of particular species are not necessarily those that would be expected if traditional or existing official koala browse descriptors are relied upon.

Appendix 2 places extant Eurobodalla eucalypt species into four categories. The table suggests different tree species' potential to play their relative parts in the browse mix for koalas in low density local circumstances [*Sheet 2*]. The placements of eucalypts within each category were suggested by examination of the relative importance attributed to them by the twenty-one sources consulted in the literature search and certain anecdotal reports [*Sheet 1*]. These patterns of relative eucalypt importance were then compared with the detailed vegetation type descriptions for each polygon in the GIS vegetation type map. This was used to try and locate potential home range areas and connectivity corridors on the map, where the mix of eucalypts in particular vegetation type polygons coincided with any potentially suitable mix suggested by the four categories.

As a general rule, a minimum of two "Apparent Potential Primary Browse Species" occurring with three from the other categories appeared necessary in connected patches of several hundred hectares. Different "Primary" and other tree species were considered capable of substituting for each other over the mosaic of a whole patch.

GIS mapping

Two digital files with overall Shire-wide map displays were produced in *pdf* format (*Appendix 5*). Scales can be chosen by zooming in and out. Over the top of the pilot study's derived habitat patches (*in one file*) and the original SCIVI vegetation type polygons (*in the second file*) as well as the boundaries for State Forests, National Parks and Nature Reserves, layers able to be turned on and off separately for viewing include:

- measured grid
- survey plots

- LGA boundary
- significant roads
- significant streams

These maps (especially the derived habitat patches and plots) help understand this pilot study report's results and discussion of suitable eucalypt types for low density habitat, the application of the theoretical tests, the cross referencing amongst RGBSAT plots and SCIVI polygons, and the speculation about potential home range size and connectivity. (The polygons in the "*Habitat potential*" file were derived from the exercise described under *Analysis* in this report's earlier *GIS chapter*.)

In terms of the questions the GIS component was asked to help answer, the results were as follows:

1. *Q: Do we have viable home ranges for low density koala populations in the Eurobodalla (in terms of range size and adequacy of the mix and density of browse species and any other factors)?* ***A: To the point that the small number of field surveys, lack of a powerful statistical control over the data inputs, modest level of complexity of the derived map and age of the base data (ie the SCIVI map) permit, there is some indication that adequate home ranges might still exist. The pilot study did not have time to measure the precise areas of the derived patches, but one way to deduce the size of potential home range areas and connecting corridors is to look at the spread of "High" and especially "Medium" potential habitat polygons, in relation to the measured grid layer in the "Habitat potential" file of Appendix 5. Non-eucalypt factors still have to be researched for their impact on the viability of such potential habitat patches.***
2. *Q: Do we have connectivity between these ranges to allow for breeding behaviour?* ***A: Examination of the derived map, combined with the role of adjacent vegetation types to enhance the potential of some polygons, appear to suggest that viable connectivity (based on eucalypt type only) might persist in some places outside cleared and urbanised zones (eg amongst the "High" apparent potential habitat in the Shire's South-East, and amongst quite large though partially fragmented patches of "Medium" apparent potential habitat in the mid-West and North-West), but that elsewhere the quality of connectivity corridors is fragmented by large intervening spaces of "Low" potential habitat.***
3. *Q: Is there connectivity with known koala populations in adjacent Shires?* ***A: There was no clear evidence obtained in the pilot study to show that any functional breeding connectivity is occurring. On the other hand the derived map and mediating literature indicate there is potential habitat connectivity with the Bermagui/Mumbulla population if ridges, logging and roadworks do not constitute an isolating barrier, and with the Monaro population if the high escarpment does not constitute an isolating barrier.***
4. *Q: What features of our Eurobodalla landscape, land use zones, tenures etc are potential enhancers or inhibitors of low density koala revival?* ***A: The pilot study concentrated on extant forest types, therefore the only potential enhancer observed was the positive finding about the number of ground-proofed polygons offering good potential habitat when the eucalypt types in the SCIVI floristic descriptors were matched with those in the relevant survey plot. The only obvious inhibitor, without further research into***

various disturbance factors, was cleared land, urban development and associated infrastructure such as the larger roads.

5. *Q: What would need to be done to implement a koala recovery strategy?* ***<u>A</u>: The pilot study did not produce data that can provide answers to this question.***

Q: If the GIS model can't answer these questions yet, how would it need to be further developed to do so? ***<u>A</u>: As mentioned previously, the model appears capable of accepting multiple additional factors for analysis, and those such as topography, weather and disturbance history would contribute to a recovery strategy design. Some of the reviewed literature dealt with the practical aspects of recovery strategies in other places, eg South East Queensland and Lismore.***

<u>RGBSAT surveys</u>
A small number of unidentified scats and scratch marks were discovered in or near an equally small number of the survey plots, but none of these can be afforded the status of evidence for koala presence. Two or three of the unidentified scats were probably Brush Tailed Possum (eg Plot T2, *Sheet 4*, *<u>Appendix 3</u>*), one set probably goanna, and the same species probably caused the scratch marks on bark. Of particular interest were the many small scats found under the *E elata* where the August 2012 koala sighting was reported at Cadgee. Although of similar shape and content to koala scats, these were too small (more the size of Greater Glider, but the wrong shape). Red deer have been seen in the area, so there was some speculation that these might be the source of the scats. If so, it was somewhat surprising koala scats were not also found under the tree, under a nearby second tree where the koala was said to have come from, or in the two adjacent Cadgee plots fully surveyed.

The best output from the field surveys was the ground proofing eucalypt inventory each plot provided (see *Sheets 3ff*, *<u>Appendix 3</u>*).

<u>Cross referencing the survey results with the SCIVI GIS map polygons</u>
Five plot surveys confirmed the eucalypt mix of the SCIVI vegetation type in which they were located (*<u>Appendix 1</u>*, *Sheet 1*).
Three plots were reasonably compatible.
One plot showed correlation only with the "Primary" species occurring in the SCIVI floristic descriptor.
Five plots were deemed partially compatible.
One plot produced virtually no correlation with its host SCIVI polygon.
Six plots produced no correlation at all.

The inconsistency when the fuzzy sets were applied [*Intersection=min{A,B,C}]* showed up across the two tables. (No third table was generated for *Fuzzy Set C – scats in relation to eucalypt types* – because no confirmed koala scats were found.)

The first table (representing *Fuzzy Set A*) displayed the SCIVI map layers according to whether they were rated High, Medium, Low or Nil potential habitat.

- Only Layer *<u>p100</u> – Escarpment Foothills Wet Forest* was rated High.
- Layers *<u>p30</u> – South Coast River Flat Forest* and *<u>p91</u> – Clyde/Deua Open Forest* were rated Medium.
- Layers *<u>eW5</u> – Wadbilliga Gorge Dry Forest*, *<u>e32A</u> – Deua/Brogo Foothills Dry Shrub Forest*, *<u>p89</u> - Batemans Bay Foothills Forest*, *<u>p90</u> – Batemans Bay*

Cycad Forest, p104 – *Southern Lowland Wet Forest* and n183 – *South Coast Hinterland Wet Forest* were rated Low.

The second table (representing Fuzzy Set B) displayed the consistency of plot findings with SCIVI layers.

- SCIVI floristic descriptors for layers *eW5* (*Plot T4*), *e32A* (*Plots TW9 and TW10*), *p30* (*Plot RUN1*) and *p91* (*Plot T11*) were confirmed as consistent.
- *p90* (*Plot BQ1*), *p91* (*Plot T3*) and *p104* (*Plot EL2*) were found to be reasonably compatible.
- *p89* (*Plot N1*) exhibited compatibility for Primary eucalypt species only.
- *e32A* (*Plot M2*), *p89* (*Plot T1*), *p90* (*Plot MERRI1*), *p104* (*Plot EL1*) and *n183* (*Plot T2*) exhibited partial compatibility.
- *n183* and *Plot BB1* exhibited virtually no correlation of eucalypt species.
- *E4 (Plot T7)*, *p89* (*Plots DRA, TW8, C2 and C3*) and *p100* (*Plot M1*) did not correlate for eucalypt species at all.

So, no intersection of Fuzzy Sets A and B was apparent.

By stark contrast, the application of the other theoretical test (graphing for suitability values) produced a strongly rising curve.

When the plot results and the SCIVI floristic descriptors for their host polygons were combined, the SCIVI vegetation types were able to be rated according to the hierarchy derived from the mediating literature, as follows (see *Appendix 1*, *Sheet 2*):

- One plot (in polygon *p89*) showed it was "No Good" for a potential low density koala browse mix.
- One plot (in polygon *e4*) showed it was only good as a supply of "Supplementary" eucalypt species.
- Two plots (in polygons *n183* and *p89*) on or close to polygon boundaries were deemed suitable when their eucalypts were combined with those in the adjacent polygon.
- Three plots (two in *p89* and one in *eW5*) were rated "Fairly Good".
- Five (in *e32A*, *p30*, *p89*, *p90* and *p104*) were rated "Good".
- Nine (two each in *e32A* and *p91*, and one each in *n183*, *p89*, *p90*, *p100* and *p104*) were rated "Very Good".

Although some polygons (eg *p89* and *n183*) were spread widely across the potential habitat quality ratings, the graph appeared to show a clear relationship between SCIVI layers and the quality of potential habitat when the floristic descriptors for SCIVI polygons and the eucalypt results of plot surveys were taken together as an indicator.

Whereas most polygons were originally predicted to have "Low" potential, the result was that an overwhelming majority appeared after ground-proofing to show "Good" or "Very Good" potential. Combine this finding with polygons like *p89* and *n183* producing the spread after ground-proofing from "No Good" all the way to "Very Good", then not only did the results of the second theoretical test appear to support the hypothesis, but they also appeared to indicate the potential of the habitat was strongly underestimated by the initial map-based predictions.

On the other hand, because the fuzzy sets outcome was not consistent with the suitability values graphing outcome, does this hark back to the weaknesses of the base data in this pilot study (eg too few surveys and no statistical control over the potential habitat ratings)? Could there have been other errors, eg is there a risk the ground-proofing was compromised by survey personnel inexperienced in eucalypt classification, or who were over-optimistic? Or is this dual finding of the theoretical tests simply confirmation that broad-scale habitat mapping has its limitations and more localized ground-proofing is essential?

Inputs and outputs through the multiple steps used in applying this pilot study's research method should always be monitored to avoid "reified boundaries" and an "artefact" of the type criticised by Scott et al [11, op cit].

<u>Evidence for the hypothesis and/or null hypothesis</u>
While the results of the second theoretical test and the finding that many plot/polygon combinations offer potentially good habitat are an encouragement to affirm the hypothesis, this pilot study in itself does not have the scientific robustness to allow conclusions to be drawn one way or the other.

Until and unless the suggested larger future study conducts widespread field surveys and the GIS modeling is undertaken with full statistical controls, multiple habitat factors and perhaps more up to date floristic polygons, observations in respect of the hypothesis/null hypothesis are essentially a choice between a "glass half full" and a "glass half empty" perspective.

On the one hand, the results of this pilot study's modest number of sampled plots combined with the appearance on the derived GIS map of reasonably large high potential patches in the Eurobodalla's South-East (eg Bodalla State Forest) and medium potential patches in the West (Deua National Park), plus historical records of koalas appearing in low quality Eurobodalla habitat, provide some preliminary evidence in support of the hypothesis ie that the landscape would support a revived low density koala population if appropriate protections were in place.

On the other hand, except for the Cadgee sighting the surveys and local knowledge have produced no firm evidence of continuing koala presence, especially in terms of resident groups or general species functionality. As well, the high and medium potential habitat patches are substantially disconnected from each other by larger low potential habitat areas. If low potential patches are assumed to be inadequate for browse, it is therefore just as possible to interpret the pilot study's findings as providing some preliminary support for the null hypothesis, ie that the landscape would not support a revived low density population.

Discussion

Strengths of the method

The pilot study appears to have established a model whereby prior research, field survey results and data on multiple post-survey factors can be fed into a GIS analysis to produce conclusions about the potential quality of habitat, including localized home range conditions, patch size and connectivity, even connectivity beyond the scale of the single Shire.

The data gathering and analysis processes are repeatable, and later inputs can progressively build upon preceding inputs. Corrections and improvements can be made retrospectively.

Further improving the method

The design of the study's theoretical model, its categories and tests were a somewhat superficial application of the advice of Scott et al. Any future full study might benefit from a more considered decision about the appropriate model, and a more comprehensive design process and application of the chosen model.

One observation (*Bulman, pers comm, 9/7/12*) was "*Have we tested the right construct? For example if the habitat is there and the koalas aren't, what other factors are in play?*"

Contested viewpoints

A 1994 expert workshop, reported by Jurskis & Potter (1997 [52, op cit]), was alert to the sensitivities, making resolutions such as:

- koala surveys and research should involve all land tenures
- it is desirable to involve community groups and academic institutions
- an independent scientific committee should oversea the [Eden region] koala research [committee subsequently established 1995].

The authors' own concluding remarks included:

> "*However koala research without direct application to management is beyond the resources of State Forests. It could be a suitable field for collaboration with academic institutions*." (p. 52)

The viewpoint is regularly expressed that koalas thrive in logged regrowth, but is treated with skepticism by anti-logging conservation activists because it is usually mentioned by foresters and loggers. The viewpoint seems sound insofar as koalas are known to favour fresh leaves, are thought also to browse on epicormic shoots and are believed to appreciate open forest with minimal understory, permitting ease of movement between trees. On the other hand it is difficult to find much recent scientific evidence for this phenomenon.

In 1997 Jurskis & Potter [52, op cit] concluded "*The studies at Eden generally supported an association of koalas with logged forests even though there was little evidence of koalas preferring smaller trees (<30 cm dbh)*" and:

> "*Richards et al (1990) stated that there were no published studies of the effects of logging on koalas. Although this may still be true, several surveys have since been reported which support an association between koalas and*

logged forests or regrowth forests. Braithwaite (1993) reported an association between koalas and disturbance including logging. Kavanagh et al (1995) found higher densities of koalas in heavily logged than in unlogged forests. CSIRO (1996) suggested that forestry operations may benefit rather than disadvantage the koala. Our observations support an association between koalas, and past logging disturbance." (P. 46)

Jurskis and Potter provided evidence suggesting koala numbers are similar in logged forests and unlogged forests eg:

> "*Extensive surveys were conducted in Murrah State Forest using tape playback and targeting areas where koalas had previously been recorded and which had been affected by integrated logging [combined sawlog and woodchip harvesting in one operation] over the last five to fifteen years. These surveys indicated that koalas were using the logged and unlogged forest mosaic. Fifty-six playbacks resulted in eight detections representing a 14% success rate. Additional playback surveys were conducted in Wallaga Lake National Park and Bermagui Nature Reserve. No logging has occurred in these areas since they were reserved about 20 to 30 years ago. Nine detections were recorded from 53 playbacks (17% success rate) suggesting that similar densities of koalas occurred in the State Forest and National Parks and Wildlife Service Tenures. Relatively high detection rates were achieved in the logging interaction surveys. Most of these surveys were conducted in the spring of 1996. Innovations in playback survey techniques included the use of two surveyors separated by about 50 metres and the playing of tapes at a moderate volume through a conventional audio system rather than a loudspeaker. Detection rates in these playback surveys were comparable to the rates of koala detections in forests on the north coast of New South Wales reported by Kavanagh et al. (1995) who did not play back koala calls. This suggests that koalas occur at lower densities in forests at Eden than in north coast forests.*" (p. 16)

and, from monitoring radio collared koalas…

> "*(b) <u>Logging disturbance</u>*
>
> *(i) Three koalas occupied mosaics of logged and unlogged forest resulting from application of the first half of the alternate coupe logging cycle (State Forests of New South Wales 1994). Their use of logged and unlogged coupes was compared with the availability of coupes within their home ranges (MCP).*
>
> *'Simon' occupied an area that was logged for sawlogs and pulpwood in 1979 under the alternate coupe system. Within its home range (MCP) there were 50 ha of logged coupes and 87 ha of unlogged coupes which appeared to be fairly evenly distributed across aspects, forest types and topographic positions. The koala was located on 28 occasions in a logged coupe and on 13 occasions in an unlogged coupe. This koala 'preferred' the logged coupes ($G=16.94$, 1 df, $p<0.001$).*
>
> *'Roberta' occupied an area which was logged between 1984 and 1989 for sawlogs and pulpwood under the alternate coupe system. Within the koalas home range (MCP) there were 149 ha of logged coupes and 391 ha of unlogged coupes. The koala was recorded on 19 occasions in logged coupes and 26 occasions in unlogged coupes. It 'preferred' logged coupes ($G=5.06$, 1 df, $p<0.025$).*

'Robert's' range partially overlapped that of 'Roberta' and had the same management history. There were 78 ha of unlogged coupes and 109 ha of logged coupes in the koalas range (MCP). It was observed 11 times in unlogged coupes and six times in logged coupes. The disproportionate use of unlogged coupes was not statistically significant. It hinged on an isolated observation about 1 km from the closest record which extended the MCP home range across a large area of logged forest.
(ii) A fourth koala ('Allan') had a home range almost entirely within an area of Bermagui State Forest which has been managed for timber production for about a century. The koala lived in pole sized regrowth forest resulting from logging and TSI9. The other four radio collared koalas occupied home ranges which had not been substantially affected by intensive logging in recent decades. All were in mixed aged forests with a substantial regrowth component created by past disturbances.
(iii) Logging Interaction Surveys at Murrah) indicated that koalas were using compartments which had been subject to integrated logging between one and thirteen years before.
Koala densities were similar in recently logged forests and National Parks and Wildlife Service reserves.

(c) <u>Wildfire</u>

The home ranges of all the radio collared koalas except 'Allan' have been subject to wildfires of high intensity and moderate frequency which have created mixed aged forests. These forests contain a mixture of usually large mature trees which have recovered from successive fires, smaller 'sapling' sized trees initiated by the last severe fire and intermediate aged trees initiated by previous fires and surviving the most recent fires. The most notable fires occurred in 1952 when many houses near Eden were destroyed (Bobbin 1989, Veness 1990).

(d) <u>Old growth forest</u>

Old growth forests are those that are relatively free from disturbance and are dominated by large, old trees (State Forests of New South Wales 1994). A history of wildfire and logging has created multi-aged forests at Eden. Surveys over more than 30,000 ha of State Forests and National Parks in 1994 classified only about 6% of the area as old growth forest (State Forests of New South Wales 1994, Figure 3). Koala records are concentrated in areas containing virtually no old growth forest and there are very few records of koalas from the few areas containing substantial quantities of old growth forest. Home range analyses did not suggest that koalas preferred less disturbed areas within their ranges." (p.31)

Jurskis and Potter also address methodological issues associated with conclusions about koala density, such as scat longevity:

"*Although it has been suggested that decomposition or disappearance of koala seats from a site may be accelerated by coprophagous insects (Allen 1995, Melzer et al. 1994), there is evidence that insect activity may sometimes enhance the durability of seats. Koala scats containing diapausing larvae of Telanepsia were remarkably resistant to mould in moist rearing containers according to Common and Horak (1994). Common and Horak (1994) deseribed Telanepsia moths with an annual life cycle whose larvae feed and pupate entirely within koala seats. Telanepsia larvae were collected in Tantawanglo State Forest in 1992 (Allen 1995). The logical implication is that* *sites containing Telanepsia have scats present throughout the year. Observations of accumulated faecal pellets with much evidence of insect feeding, together with the intact shells of faecal pellets following the completion of life cycles of coprophagous insects (Melzer et al. 1994) suggest that durability of seats and coprophagy are not mutually exclusive. Common's and Horak's (1994) observations suggest that they are sometimes complementary.*" (p.18)

and the utility of survey methods for regional scale predictive modeling, as distinct from patch-scale operational [*presumably forestry*] purposes…

"*The dispersion of koala activities over large home ranges indicates that very intensive, costly and time consuming surveys are required to confidently assess presence or absence of koalas or the distribution of koala activity at a site. Such surveys are not logistically appropriate for stratified regional surveys to obtain information for predictive modelling. On the other hand, information on the durability of koala scats and the concentration of koala activities in patches within larger home ranges indicates that searching for scats can be a very reliable method for determining presence or absence of koalas for operational purposes*." (p.20)

When asked by the researcher for this pilot study (10th May 2012), Rod Kavanagh pointed out "There have been numerous observations of koalas feeding on young trees including a NSW Department of Primary Industries study by [himself] and others of koalas utilizing very young (<7 years) eucalypt plantations on farms near Gunnedah (publication pending), but the one published paper that addresses the direct impact of a logging operation seems to be [Kavanagh et al (2007)]. It is an experimental study of selective logging where the main koala food trees were not logged, only a proportion of the White Cypress Pine component of the stand basal area. The logging activity did not appear to adversely affect the koala population [136]. The thesis for a PhD project including before-and-after logging observations near Coffs Harbour, by Sally Radford, has not yet been completed and no publication is yet available".

The 2004 Regional Forests Agreement CAR Reserve Map [137] can be interpreted as providing graphic support for the standpoint that it is not cost-effective to search for or try to enhance protections for koalas in areas like State Forests, in tandem with the assertion that the Comprehensive Regional Assessments ensured Forests and National Parks were appropriately placed for wildlife protection, and the Threatened Species Licence provisions under the Regional Forest Agreement were adequate (see *Hypothesis*, p.27, above).
It appears very visually obvious in this map that potential habitat connectivity already exists (depending on the eucalypt types present) through the linked National Parks lying South, West and North of Eurobodalla, all the way from Kooraban NP to Morton NP (via Wadbilliga, Deua and Monga). If there's to be a future large study on potential revival through either natural growth or translocation incorporating landscape scale connectivity corridors, the argument might still stand up that it remains technically feasible and politically easier to ignore the State Forests and concentrate on proofing vegetation types, topography and other habitat factors (like microclimates, soil nutrients and disturbance) in the National Parks. Because the relevant parts of the National Parks are so remote from human population centres and accessible only by 4WD vehicle and on foot in good weather, the answer might depend on a prerequisite community political decision about whether we want wild

koalas to live closer by (and even amongst) us. It might also depend on whether the rugged country in the Eurobodalla's West is suitable for koalas in terms of topography and aspect, by comparison with more benign rural and urban landscapes elsewhere. The Gold Coast and Lismore examples demonstrate that free-ranging koalas don't necessarily need to be in wild forests. One option for avoidance of localized extinction might be for rural and urban human populations to learn to cooperate with, rather than compete with koalas for habitat.

Outcomes of the pilot study

As well as its production of an apparently workable research model, the pilot study has provided clear parameters for a full scale research effort to follow, perhaps linked to the efforts in the Bega Valley Shire and elsewhere, resourced by the Commonwealth Biodiversity Fund.

Suggested further research

<u>Literature Search</u>
A more comprehensive and systematic search of literature on browse species suited to adapting low density koala populations, especially as new research continues to emerge, will refine and perhaps correct the tentative findings of this pilot study. This work needs to be linked to evolving new definitions for "core", "secondary", "supplementary" or other classes of habitat. Literature pertaining to recovering populations would be of particular value.

<u>Habitat factors</u>
The full set of apparent conditions for viable low density habitat needs to be analysed for each of the patches identified by this pilot study as potentially suitable. This includes those conditions not fully addressed by the pilot study such as: size and crown class of trees; foliage cover scales; soil nutrients; altitude; steepness of slope; distance to viable water source; various disturbance types; and, microclimate. The latter (microclimate) is related to the ground-proofing surveys proposed below for remote and wilderness locations on the Escarpment. The pilot study's method and GIS model have provided the basis for all this work on additional habitat factors, and if resources are constrained each could be researched, analysed and applied to the basic model one at a time. The technique is simply to apply other habitat factors by adding relevant layers or switching off barriers in the GIS display. Resources permitting, this work could be enhanced by utilizing the full-range spectral data (visible VIS), near infrared (NIR) and short wave infrared (SWIR) available through airborne sensors. The CSIRO and others began some of this activity in 2012. Specialized data collection for the Eurobodalla might be negotiable as an incidental part of a happenstance flyover for other purposes, or the relevant private companies might be engaged (costing is available).

<u>Surveys</u>
Obviously a comprehensive Eurobodalla-wide plot survey program in the Forests NSW, NPWS and some private tenures remote from routine public observation, is needed to confirm whether there are any resident koalas left.

In respect of connectivity to the Monaro (known populations from Numeralla northward) and the headwaters of the Shoalhaven River (koalas present on private land), a survey program for the logistically challenging Deua National Park (as well as Wadbilliga National Park and Dampier State Forest) remains part of this important unfinished business. The suitability or otherwise of the Eurobodalla's higher Great Eastern Escarpment habitat needs to be tested, eg in wilderness West of Belimbla and Merricumbene. The Numeralla surveys show koalas occupying cold, dry, poor-soil patches at altitudes up to 1,000 metres, beyond the previously acknowledged maximum of 800 metres, according to specialist Chris Allen (*discussion with researcher - 1st September 2011*).

The polygons classed as "medium" potential habitat (based on eucalypt type only) in *Appendix 5* appear to link habitat of the known Monaro/Southern Tablelands koalas with reasonably large areas south of Clyde Mountain and between Bendethera and Dampier Mountain. Accordingly, the volunteer Eurobodalla Koalas project is considering a ten-plot survey expedition to the Dampier Mountain area in Autumn 2013.

The polygons in *Appendix 5* also suggest quite extensive "high" quality potential habitat in the South-East of the Shire in Moruya and Bodalla State Forests, forest surrounding Gulaga Mountain and surrounding Wagonga Inlet. More intensive surveys of these less remote areas, and of places like the Nerrigundah, Merricumbene and East Lynne districts seem warranted when koala records, the preliminary results of this pilot study's GIS mapping and research findings about movement paths through fragmented patches are considered together. This pilot study's preliminary map analysis also suggests it remains possible there could be a sustaining vegetation corridor between Sam's Ridge and Cadgee, if dispersing koalas can negotiate high ridges, Logging Compartment 3064 and the Tuross River. Two popular *youtube* videos in October 2012 demonstrated that swimming is not a problem for hungry koalas. The Tinpot surveys might therefore need to be expanded.

State and private forests

As previously discussed, the age of the available vegetation type maps is an issue. A proper analysis is required of the extent of disturbance and other conditions in this pilot study's nominated potential habitat polygons, that might have resulted from Forests NSW activity and private forestry, especially since the time the field surveys were done for the SCIVI and CRA vegetation type maps. At the very least, six years have passed since the maps were published, and many more years might have passed since their ground-proofing was done (Tozer, 2006, indicated that the SCIVI data were drawn from sources including previous studies [122 op cit, *Metadata*].

Estimates therefore need to be made about whether forestry activity has left the polygons in the same state as implied by these available maps or whether the floristic descriptions for, say post-2000 logged patches or silviculture areas would now need to be revised. Relative abundance of species, and class-size and ages of trees within affected patches might now be different. If so, the significance of the changes would need to be investigated.

As suggested in *Suitable range areas and adequate connectivity corridors* (p.39, above) if this difficulty can be overcome, the Eurobodalla Koalas project has the potential to offer a practical contribution as a case study for the NSW Government. (See discussion paper – *Review of the Native Vegetation Regulation: Private Native Forestry and Koalas* [125, op cit].)

The next GIS model
The GIS model should be enhanced and reviewed continually. GIS software is being renewed constantly. A more intensive, sophisticated effort in model building and the use of the many tools available through *ArcGIS* is warranted.

Better statistical controls
Statistical shortcomings in some of the pilot study's important sources were identified early (eg problems with validity for prediction using the 2010 Bermagui/Murrah RGBSAT analysis [27, op cit], and Welsh et al, 2010 [112, op cit]). The pilot study itself presented obvious statistical challenges because of its data quantity limitations. In addition, the pilot study's theoretical design and methodology had to be conceptualized with statistical issues in mind. To better address some of these aspects in any future full study, the extended capabilities of the *ArcGIS Desktop* software used for the mapping methodology could be applied. The extension called *ArcGIS Geostatistical Analyst* permits a user to evaluate measured spatial data according to statistical principles. Value distributions of datasets can be explored, compared to normal (bell-shaped) distributions and to each other, and queried for correlations between different types of data. Maps can be made of predicted values at unmeasured locations. The creators claim *ArcGIS Geostatistical Analyst* provides wider choice of predictive models, more control over their parameters, and statistical techniques for assessing the quality of the results (Ormsby et al 2009 [13, op cit, *page 17*].

The chapter on GIS describes an exploratory reading-based analysis where polygons in the SCIVI map were classified for their likely suitability as low density habitat, according to the mix and frequency of occurrence of selected eucalypts in the SCIVI vegetation type floristic descriptors. This is one aspect of the GIS model for which other refinements are suggested in *Habitat factors*, above. The eucalypt species polygon classification exercise needs to be repeated within a properly controlled statistical framework, and linked integrally to any other habitat parameters being analysed in a future study. For flora, aspects like mix and frequency of occurrence are already entered into the SCIVI floristic descriptors in a carefully structured way, so that structure would most likely provide the basis for a statistical control method.

Mitchell (2012) [138] has developed some decision rules for assigning habitat classes to mapping. His work might form the basis for an improvement on the preliminary polygon coding tried by this pilot study. Mitchell considers "primary habitat" to be areas where primary koala food tree species comprise at least 50% of the overstory trees. His classification then grades through "secondary habitat Class A" and "secondary habitat Class B" to "secondary habitat Class C" (secondary and supplementary food tree species comprise <30% of the overstory trees and primary food tree species are absent). Mitchell has attempted to consistently assign classes by defining the terminology used in Remnant Ecosystem descriptions – the *REDD database (RE_v7.0_2012)* and was able to use quite precise separation and ratio descriptors for emergents, co-dominants, density, scattering, frequency etc.

Extending the project to encompass multi-species habitat corridors
During the progress of the pilot study, staff of the Eurobodalla Shire Council expressed interest in developing a GIS mapping approach to multi-species habitat corridors across the LGA. The model tested in this pilot study appears adaptable for

multiple species. For example the RGBSAT plot sampling technique could include a wider range of fields on the data sheet, the literature on habitat for other species could be used to rate the potential of habitat in the same way the pilot study has done for koalas, and the inputs and processes of the GIS analysis and theoretical error-testing could be carried out in parallel.

Assessing public attitude towards a recovery program

It has been implied in this report that a recovery program for the Eurobodalla koala might be warranted. This would seem to depend on the whole community and its institutions developing a strong enough will to support and implement substantial changes to daily lifestyle, pet control, urban planning, peri-urban planning, infrastructure and industry, farming practices, forestry practices, national parks resourcing etc.

On the one hand, this study's plot surveys and collection of local knowledge so far suggest it could be documenting the functional extinction of koalas in the Eurobodalla. Even if so, the task is important because the whole community needs to confront and accept responsibility for the event and abandon the denialism described in *Need for the Study*, p.7 (above).

On the other hand, the preliminary GIS mapping suggests it is not too late for a recovery strategy. Whether or not the community decides to give priority to a recovery strategy, it is incumbent upon those who care to prepare the way by pursuing the additional data and using the study's findings to describe the strategy's features.

Aspects of a recovery strategy design

This pilot study has not addressed the details for a local recovery strategy, but some of its sources (eg *Coffs Harbour City Koala Plan of Management* [139], the *Redland Shire Council Action Plan* [140] and more recently the Lismore exercise [109, op cit]) have done so for other LGAs. If resources can be found to conduct the suggested major follow-up potential habitat research in the Eurobodalla, the design of a recovery strategy could be an integral part. Indications from the pilot study are that this would not be a difficult task.

Conclusions

The authors are confident the research model tested by this pilot study is adaptable to a larger future study. It is capable of examining potential habitat for koalas in low density circumstances across the Eurobodalla landscape (and elsewhere) by incorporating the full range of habitat factors with a statistical control in its GIS component. Several sub-projects could be built upon the groundwork covered by this pilot study, such as a local history of koalas, and investigations into the local effects on habitat of urban and peri-urban development and forestry.

It is recommended that such a study be pursued, comprising a large number of RGBSAT survey plots at strategically selected places, and refinement and enlargement of the GIS analysis using the latest available vegetation type polygons, preferably with direct technical input from expert agencies holding contemporary data, such as Forests NSW and the Office of Environment and Heritage. Such a study would put to rest any question about localised functional extinction and could include a recovery strategy design.

The pilot study itself does not possess the robustness to draw conclusions in respect of its hypothesis and null hypothesis, but has provided some preliminary indicators about the probable status of koalas in the Shire and, in respect of eucalypt species at least, the status of necessary home range and connectivity conditions.

Except for the August 2012 Cadgee sightings, which might represent a dispersing animal, there is so far no evidence of koalas persisting in the Eurobodalla since the 2009 Nerrigundah sightings. The impression is that Eurobodalla koala numbers, always sparse since the mid-20th Century, were at a critical point by about the year 2000.

The pilot study's exploratory derived GIS map appears to show patterns of higher quality potential browse species mix in the Shire's South East (Moruya and Bodalla State Forests), and medium quality potential browse species mix in the Shire's West (Deua National Park). These patches appear large enough to sustain low density resident groups. Connectivity between Eurobodalla patches and with patches in adjacent LGAs appears variable. Large areas of low quality potential browse species mix appear across the Shire. There appear to be isolated pockets of high, medium, low and nil potential browse species mix elsewhere across the landscape. All these conclusions need to be revisited through a more robust analysis, however.

Peer review, other contributions, and acknowledgements

Peer review of the pilot study (on a modest scale) began from the outset, in an attempt to ensure all concepts and processes were subject to ongoing scrutiny from academic, community and operational perspectives. Updated drafts of the pilot study report were circulated several times throughout 2012, with requests for feedback, for example the first circular asked for particular attention to the theoretical construct and the hypothesis, whereas the final circular focused on the quality of analysis and validity of conclusions.

Peer reviewers considered the study's theoretical basis and methodology to be sound. There was discussion about the employment of the hypothesis and null hypothesis, requiring the lead researcher to decide whether to keep them. One argument was that an hypothesis approach is not appropriate to studies of Australian biodiversity, because Australian ecology refuses to conform to neat and tidy parcels. Inconsistencies, fluidity and unpredictability exist in Australian climate and population patterns, and in the way wildlife uses territories and responds to seasons and weather. A contrary viewpoint was that worthwhile simplicity and best scientific rigour would be obtained if data were applied to the null hypothesis only, as in many experimental studies. The third viewpoint was that the null hypothesis is a distraction and would not significantly assist in removing potential researcher bias; hence it is best to apply data to the hypothesis only, while simply keeping the null hypothesis in mind. The ultimate decision was to apply data and findings to the hypothesis where possible, while keeping the null hypothesis in mind. Future follow-through research might not need to include hypotheses, but inclusion at the pilot stage was considered worthwhile as one indication of the range of possible approaches and in an attempt to test the option.

A comprehensive, chronological running record of project activities was maintained, at the level of detail of email content, daily events and content of related documents like funding applications, media statements and reports to participants. This running record was also the device for capturing informal oral inputs (eg local historical memories and other relevant remarks). It is available on request.

A *Facebook* group called *Eurobodalla Koalas project* was established in September 2012. Postings and other information can be viewed at
http://www.facebook.com/#!/groups/187171881416765/

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Appendices

(separate digital files)

Appendix 1 (theoretical tests schematic) – *Excel*

Appendix 2 (sources and classification of low density eucalypt browse species) – *Excel*

Appendix 3 (detailed cross referencing and vegetation type analysis) – *Excel*

Appendix 4 (classified polygons after literature search) – *Excel*

Appendix 5 (GIS maps) - *pdf*