KOALA SURVEYS
ECOLOGY AND CONSERVATION
AT EDEN

by

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FOREST RESEARCH AND DEVELOPMENT DIVISION
STATE FORESTS OF NEW SOUTH WALES
SYDNEY
1997

Research Paper No. 34
August 1997

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Published by:

Forest Research and Development Division,
State Forests of New South Wales,
121-131 Oratava Avenue, West Pennant Hills, 2125
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Australia.

DDC 599.2099447
ISSN 1324-3829
ISBN 0 7310 9142 6

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SUMMARY

This paper summarises information obtained since 1990 from a koala survey and research program at Eden including preliminary information published in Research Paper No 22 - *Survey Techniques and Aspects of the Ecology of the Koala near Eden* by Jurskis *et al.* (1994).

Intensive, systematic surveys for koala scats were a reliable but costly method for detecting evidence of koalas in low density populations. Playback of taped male koala calls achieved a relatively high response rate in the Bermagui-Murrah area and allowed sites to be targeted for more intensive systematic surveys. Playback at a moderate volume level in spring may be more effective than using calls amplified through a megaphone and/or surveying at other times of the year.

Data describing the use of trees and forests by koalas at Eden are presented together with data on the physiology and genetics of the koalas. Surveys and radiotracking studies have continued to support an association of koalas with dry and/or disturbed forests at Eden. This is consistent with information from other studies. No dense aggregations of koalas have been identified in the Eden 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 survey and research. There is evidence that forestry may not impact detrimentally on koala populations and may have beneficial impacts in the long term. Nevertheless very conservative management of State Forests at Eden for koala conservation will continue. There has been little koala survey or research conducted in National Parks or private lands 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.

INTRODUCTION

Early in this century, the previously abundant koala population in the region surrounding the Bega Valley suffered a precipitous decline which coincided with the end of the major agricultural clearing and development phase (Lunney and Leary 1988). Since then koala sightings have been rare but widespread in the Region (Figure 1, Lunney *et al.* 1997).

Late in the 1980s concerns were raised about possible deleterious effects of forestry operations, especially integrated[1] logging, on koalas in the Eden region (Jurskis *et al.* 1994). In response to those concerns a survey and research program was instituted by State Forests of New South Wales and the New South Wales National Parks and Wildlife Service in 1990 with the aim of developing a regional management plan for koalas. Jurskis *et al.* (1994) reported some preliminary information from that program. Non-government organisations such as the Tantawangalo Catchment Protection Society (TCPA) have also studied koalas in the Region (Allen 1992 unpubl.[2], Allen 1995). Lunney *et al.* (1997) reported the results of a postal survey conducted in 1991/92 to gather information on the regional distribution of koalas.

The koala survey and research program at Eden was reviewed by an expert workshop in 1994 (Cork *et al.* 1995) resulting in a list of suggested resolutions (Appendix 1) which are paraphrased as follows:

- The first priority is a comprehensive study of koala autecology (in areas under moratoria on forestry operations) focusing on populations and socioecology rather than individual koalas.
- Efforts should continue to locate further substantial koala populations in the region and replicate autecological studies.
- A feasibility study of using dogs for koala survey should occur.
- A critical assessment of the reliability of scat-based koala surveys should occur.
- A stratified regional survey for koalas should be carried out, when methods for dealing with rarity are developed, so that a robust habitat model can be constructed.
- Logging effects studies should not occur until methods are devised to allow statistically unequivocal testing of clear hypotheses. In the meantime data collection on previous logging and koala interactions should be maximised.
- Koala surveys and research should involve all land tenures.
- It is desirable to involve community groups and academic institutions in the surveys and research.
- If reliable survey and monitoring methods are developed, experimental manipulations of koala populations/habitat should be considered.
- An independent scientific committee should oversee the koala research.

More than two years have elapsed since the expert workshop was held. An independent research committee was established in June 1995. It may now be appropriate to review the progress of the koala study program against the resolutions.

[1] Harvesting of sawlogs and chipwood in a combined operation

[2] Allen, C. (1992). Koala Habitat Survey of the Devils Creek Catchment. Unpublished report to the Australian Heritage Commission.

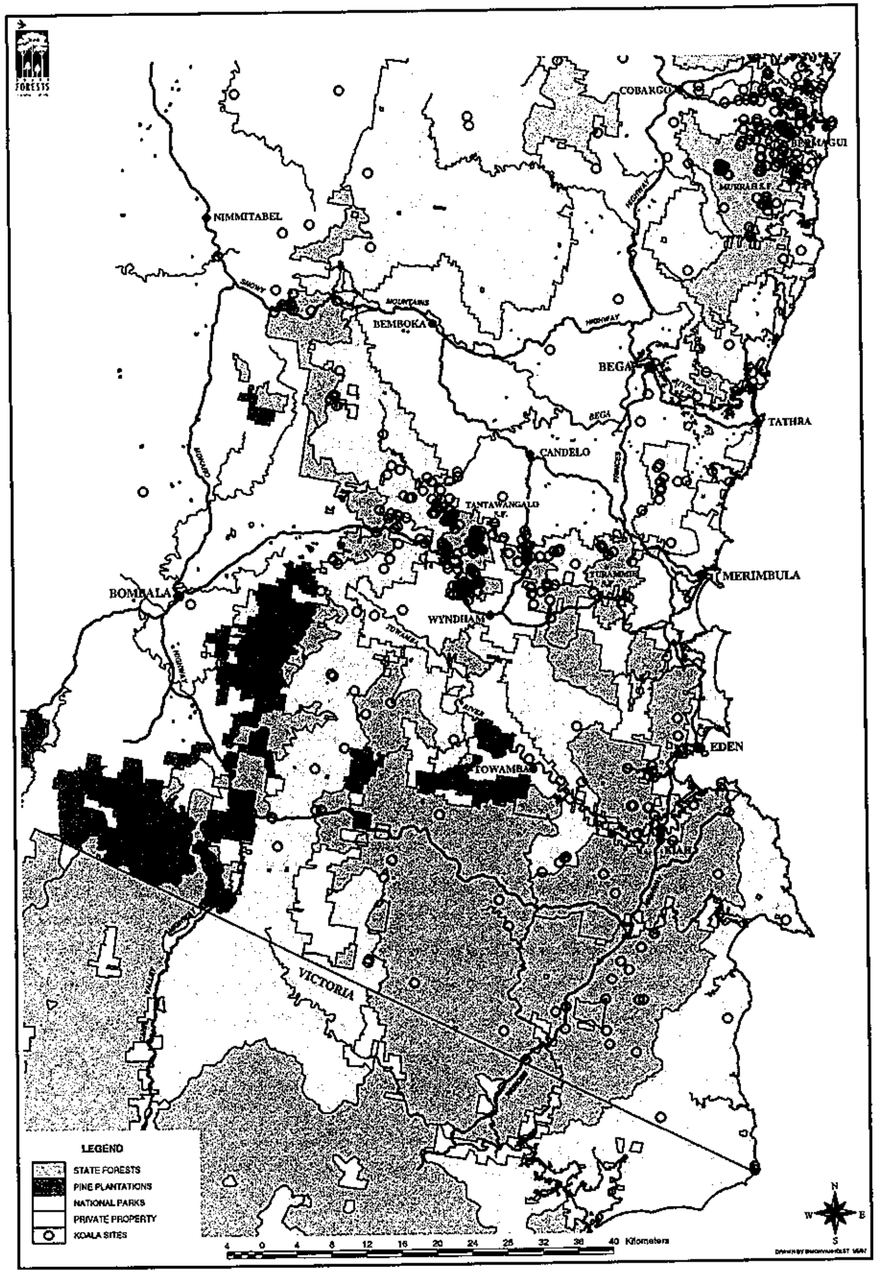

Figure 1. Eden region: localities, land tenure, koala records.

1. *AIMS*

This paper aims to summarise information collected by the koala survey and research program at Eden since 1990 including the preliminary data reported by Jurskis *et al.* (1994). A further aim is to assess progress against the objectives suggested by the expert workshop (see above) and review the relevance of the objectives. This should facilitate a review of the survey and research program and assist in the development of the regional koala management plan.

2. *THE STUDY AREA*

(a) *Environment*

The study area is the Eden Management Area (State Forests of New South Wales 1994) in the extreme south east of New South Wales. It extends south from near Bermagui on the coast and east from the Monaro Tablelands around Bombala and Nimmitabel (Figure 1).

Three broad landforms occur in the study area (State Forests of New South Wales 1994). They are the tablelands, the escarpment and foothills and the coastal hills and valley landforms. The tablelands and coastal hills and valley landforms have undulating topography and are mostly privately owned lands which have been substantially cleared and developed for agriculture. The escarpment and foothills landform comprises more steeply dissected lands which are mostly forested crown lands.

Four broad geological groups have an extensive distribution in the region (State Forests 1994). These groups (igneous intrusive, igneous extrusive, sedimentary and alluvial) contain a large number of geological types which were mapped by Beams and Hough (1987) (unpubl. data)[3].

Thirty-seven Forest Types (Forestry Commission of New South Wales 1989) have been identified in the State forests of the study area (State Forests of New South Wales 1994). Twenty-three of these Types from which data in this paper have been collected are described in Appendix 8.

(b) *Land use and forest management practices*

Twenty percent of the forests in the region are privately owned. Following the Interim Forest Assessment, forty-two percent of the regions forested land is reserved in National Parks and similar tenures. A further seven percent is classified as Deferred Areas which are receiving further consideration in the Comprehensive Regional Assessment. Thirty-one percent of the forests are multiple use State forest. This area includes filter strips, riparian buffers, habitat links and other areas which are not used for timber production. Within the State forest area which is notionally available for logging, an alternate coupe system is applied to disperse the immediate impacts of logging operations over space and time (Jurskis *et al.* 1994). The individual coupes selected for logging are not subject to clearfelling. About thirty to forty percent of the trees within the actual logged area are retained for various purposes including further sawlog growth, seed supply and wildlife habitat value. Thus logged coupes retain a mixed age structure which is enhanced as regeneration progresses.

Prelogging surveys of coupes proposed for logging are routinely carried out to identify any special values (biological, archaeological, historical etc) which may be present. Logging operations are then modified or excluded where necessary to protect these values.

[3] Beams and Hough (1987). Explanatory notes to accompany geological map of the Eden forestry region, New South Wales. *For. Comm. NSW Misc. Pap. No. 960.* 9 pp.

Specific surveys for koalas are triggered by proximity to prior records or koala evidence found during prelogging surveys. Where areas used by koalas are identified, a special protocol is applied to manage the areas specifically for koala conservation (Jurskis *et al.* 1994). This involves reserving the areas and linking them to existing reserves as well as applying appropriate fire protection and predator control programs (Ridley 1993). Since 1994 two areas of State Forest where most koala records have been concentrated, at Tantawangalo-Yurammie and Bermagui-Murrah (Figure 1), have been subject to moratoria on forestry operations (Cork 1995) to protect koalas.

PART A - SURVEY TECHNIQUES

INTRODUCTION

Lunney *et al.* (1997) reported a postal survey which gathered information on the regional distribution of koalas over the latter half of this century. They concluded that koalas have been scattered through the region in low numbers for the last 40 years.

Allen (1995) concluded that a breeding population of koalas occurred in Tantawanglo State Forest where koalas were regularly sighted. He reported that three koalas were seen during 310 person days survey of two sites in Tantawanglo State Forest. The combined area of the two sites is probably in the order of 100 ha.

Jurskis *et al.* (1994) discussed the koala survey techniques which have been employed at Eden, *ie* searching trees either in daylight or with a spotlight at night, looking for scratch marks on tree trunks, searching the ground for faecal pellets, playback and listening for koala vocalisations and analysing predator scats for the presence of koala hair. They noted that these techniques were either ineffective (looking for scratchmarks) or had an extremely low success rate. One technique, searching for faecal pellets or 'scats', was often successful in detecting additional evidence of koalas in the course of following up incidental records while the other methods were almost invariably unsuccessful. This situation contrasts with many published studies which have used periodic tree searches to estimate tree preferences, habitat use and population levels (Jurskis *et al.* 1994).

METHODS

Extensive surveys have been carried out to obtain information on the distribution of koalas within the region and within the logged and unlogged forest mosaic at Murrah. Intensive prelogging surveys (Appendix 2) involve systematic day-time searching for evidence of koala presence (animal, scratch marks, heavy browsing, scats), night-time spotlighting and tape playback in proposed logging areas. Where evidence of koalas has been detected in prelogging surveys or by other means, follow up or 'asterisk' surveys (Appendix 3, Lunney and Moon 1993) may be conducted either to gather information which is used to modify proposed operations to ensure koala conservation (Ridley 1993, Jurskis *et al.* 1994) or to gather general ecological information on koalas.

Surveys by State Forests of New South Wales since those reported by Jurskis *et al.* (1994) are described hereunder. The efficacy and efficiency of various techniques are compared and results are contrasted with a published survey from northern New South Wales (Kavanagh *et al.* 1995). Literature on the durability of koala scats is briefly reviewed.

RESULTS

1. *REGIONAL KOALA PLAYBACK SURVEY*

A survey of 140 randomly selected sites across the region using spotlighting, listening and playback of taped calls of male koalas detected four koalas during spring and summer of 1993/94 (Jurskis unpubl.). The success rate of 3% was very similar to the 2% detection rate of Kavanagh and Bamkin (1995) who did not use taped koala calls. Although many of the sites were close to recent incidental records of koalas or radiotracking study sites (Figure 1, Figure 2, Part B of this report) no responses were recorded at these sites suggesting that playback is not a consistently reliable technique for koala surveys. However a higher success rate has been achieved in recent surveys at Murrah as detailed below.

2. *REGIONAL NOCTURNAL FAUNA SURVEY*

Another survey of 220 randomly located sites in the region (Kavanagh unpubl.) using the methods of Kavanagh and Bamkin (1995) detected only three koalas (1% of sites) in autumn 1994. The consistently low detection rate of koalas in regional surveys at Eden contrasts with the much higher detection rate in New South Wales north coast forests where koalas were detected at 12% of survey sites (Kavanagh *et al.* 1995).

Codes for sites mentioned in text:

A Ruth, B Simon, C Wayne, D Bob, E Roberta, F Robert, G Michelle, H Allan.
1 Wolumla Peak, 2 Wyndham Trig 1, 3 Wyndham Trig 2, 4 Cpt957, 5 PP adjoining Tantawangalo, 6 Cpt921, 7 Brown Mountain, 8 Cathcart, 9 Coolangubra, 10 Honeymoon Ridge, 11 Syndey, 12 Cpt2032. (Sites 1 to 6 were discussed by Jurskis *et al.* (1994)).

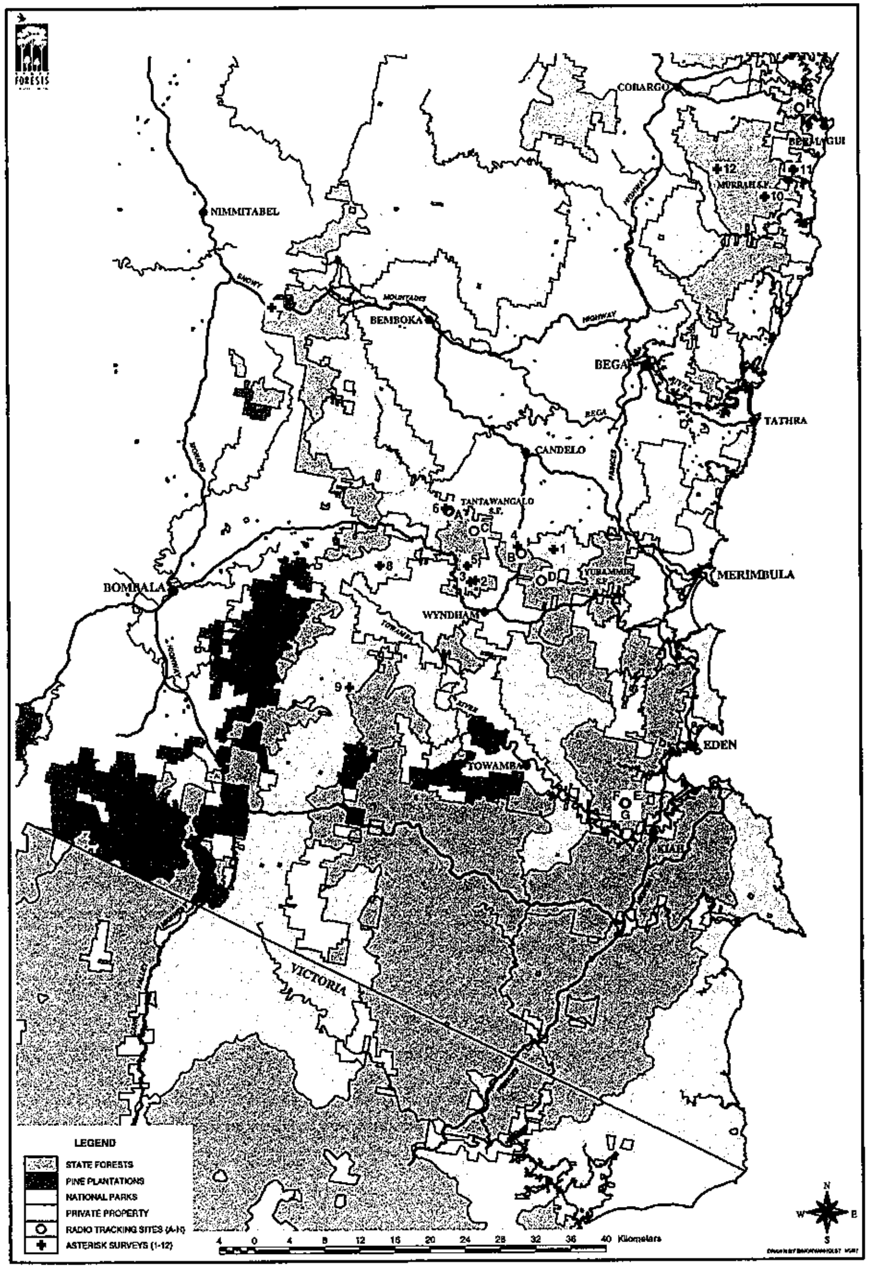

Figure 2. Location of radio-tracking and follow-up survey sites.

3. *LOGGING INTERACTION SURVEYS AT MURRAH*

In order to gather data on previous logging and koala interactions, as suggested by the expert workshop, 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 over the last five to fifteen years. These surveys indicated that koalas were using the logged and unlogged forest mosaic (Table 1). 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 (Table 1). 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.

Table 1. Results from extensive surveys of the logged/unlogged forest mosaic at Murrah.

Survey year	Compartment	Logging year	Past detections	Current detections
	(2016	1982/83	1994	Yes
1995/96	(2019	1983/85	1986, 1993	No
	(2040	1984/85	1986	Yes
	(2041	1984/85	1989, 1994	Yes
	(2010	1987/88	No	Yes
	(2012	1988/89	No	No
	(2015	1988/89	No	Yes
	(2016	1982/83	1994, 1996	Yes
1996	(2021	1990	No	No
	(2032	1982/83	1995	Yes
	(2041	1984/85	1989, 1994	Yes
	(2049	1995	1996	Yes
	(2050	1995	No	No
	(2056	1988/89	No	No
	(2057	1988/89	No	No
	(2062	1995/96	No	No
	(2063	1995/96	No	No

4. *PRE-LOGGING KOALA SURVEYS*

Most of Tantawangalo and Yurammie State Forests have been subject to moratoria on logging operations, therefore prelogging koala surveys have been concentrated in Murrah State Forest which has many historical koala records.

Prelogging surveys (Appendix 2) in Murrah State Forest detected koalas in three compartments. The playback surveys were far more efficient in detecting koalas than searches for scats (Table 2). Following detections intensive ground searches for scats were implemented and harvesting plans were modified using results from these ground searches to avoid disturbing koala habitat.

Prelogging detections in compartments 2049 and 2032 were followed by 'asterisk surveys' (Appendix 3) to determine a regular use area (Jurskis *et al.* 1994, Ridley 1993).

In Compartment 2049 the initial detections were responses to tape playback. Transects with quadrats resulted in detection of koala scats in two areas. The follow up 'asterisk survey' process resulted in nine additional scat locations in the same two areas. Under agreed protocols the regular use areas and buffers were linked to undisturbed forest such as filter strips, wildlife corridors uncut coupes or adjacent National Parks (Ridley 1993). In Cpt 2049 a buffer zone of 180 ha plus corridor links approximately 1200 m long and 100 m wide were established. Following this process an amended harvesting plan covering 25 ha of the original 102 ha notionally available for logging was submitted to the National Parks and Wildlife Service and subsequently licensed for harvesting.

Table 2. Pre-logging surveys Murrah State Forest.

	Area (ha)	Tape playback		Transects		Operational
	surveyed	Man hours	Koala records	Man hours	Koala records	Records
2180/81	89	6	-	160	-	
2050	50	6	-	45	0	
2049	102	8	2	105	2	
2047	68	6	-	45	-	
2050	60	6	-	90	-	
2030	58	4	-	45	-	
2046	60	6	-	96	-	
2048	69	6	-	45	-	
2056/57	102	9	-	45	-	
2024	98	7	-	31	-	
2032	109	6	1	120	2	
2035	135	7	-	45	-	1

In Compartment 2032 scats were detected under two trees in intensive transect surveys. There was subsequently a playback response and two additional trees with scats were detected in a follow up 'asterisk survey'. Operational plans for this compartment have not been finalised.

A koala was detected by a logging contractor in Compartment 2035 when only a small area of the compartment remained to be logged. Logging operations were abandoned following the detection.

5. *FOLLOW-UP SURVEYS*

Six 'asterisk' surveys (Figure 2) following up koala detections have occurred since those reported by Jurskis *et al.* (1994). All of these surveys using scat searches have yielded some additional evidence of koala. Information from these surveys is included in Part B of this report.

6. *DOG TRIALS*

A professional dog trainer was contracted to supply and train two dogs to locate koalas and faecal pellets by smell. Although the dogs were able to find fresh scats in 'dummy runs' they tired quickly and were unable to find scats in known koala home ranges. There was opposition to the trials from a section of the community and no further trials have been conducted even though there would seem to be potential benefits in increasing survey efficiency (Jurskis *et al.* 1994). The trials suggested that intelligence and stamina should determine the appropriate breed of dog as much as olfactory ability. To work effectively in the Eden forests, dogs would have to be able to be controlled by voice commands since use of leads was not practical in dense undergrowth. However efficient detection of reasonably fresh scats (perhaps one or few months old) by dogs seems a distinct possibility.

7. *RELIABILITY OF SCAT-BASED SURVEYS*

(a) *Monitoring of scats*

Rowell and Jurskis (unpubl. data)[4] established six plots to monitor scat longevity. Four were established in known koala habitat in dry forest and two were in wet forest not known or expected to be used by koala. Between 10 and 40 fresh scats were introduced to each plot. Except for one plot with only ten scats, the scats persisted from nearly one year to more than two years in dry forest and from six to 12 months in wet forest. Data are summarised in Appendix 4. Although Allen (1995) reported rapid disappearance or disintegration of koala scats, he used a small number of scats which had already aged for an indeterminate period. An unspecified number had already been subject to coprophagy by insect larvae.

(b) *Published information on insect coprophagy*

Although it has been suggested that decomposition or disappearance of koala scats 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 scats. 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) described *Telanepsia* moths with an annual life cycle whose larvae feed and pupate entirely within koala scats. *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 scats and coprophagy are not mutually exclusive. Common's and Horak's (1994) observations suggest that they are sometimes complementary.

[4] Rowell, D. and Jurskis, V. (1994). Fate of koala scats on the forest floor. State Forests of New South Wales Internal Report (Draft).

(c) *Published information on scat-based koala surveys*

Lunney and Moon (1993) described field survey based on koala scats as a quick and practical method which has been successfully used to provide information for planning or modifying developments (to conserve koala habitat). Curtin and Lunney (1995) found that most localities at which koala scats were detected in a large reserve near Sydney contained scats that were at least 12 months old having been scorched by the 1994 wildfires. Phillips and Callaghan (1995) stated that areas of major koala activity have a relatively high rate of faecal pellet deposition and that the significance of habitat can be determined by collecting data on the presence or absence of faecal pellets.

DISCUSSION (SURVEY TECHNIQUES)

It seems likely that the relatively high detection rates of koalas in recent playback surveys were due to innovations in techniques and timing. The use of two observers and moderate playback volumes probably increased the chance of detecting responses as well as the precision of location estimates. This could help to avoid double counting of responses from single animals. Previously, playback surveys were mainly carried out during summer. Scheduling these surveys earlier in spring may prove more effective. Appropriately timed and executed regional playback surveys may allow the regional distribution of koalas to be more clearly defined. However the apparent seasonal variation in response of male koalas to playback and lack of response of female koalas to playback made this method unsuitable for determining fine-scale presence/absence of koalas for operational purposes.

The dispersion of koala activities over large home ranges (Part B of this report) 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 (Part B of this report) indicates that searching for scats can be a very reliable method for determining presence or absence of koalas for operational purposes.

Dogs have been successfully used to increase wildlife survey efficiency in other areas (Zwickel 1971). Further trials of sniffer dogs could be conducted at Eden if more general community support was apparent.

PART B - ECOLOGY OF KOALAS AT EDEN

INTRODUCTION

Data on the use of trees and forests by koalas at Eden have been gathered in the course of follow up surveys as described by Jurskis *et al.* (1994) as well as by monitoring eight radio collared koalas since 1991. Although Jurskis *et al.* (1994) reported some preliminary data from these studies, their analyses were limited by a lack of data on smaller 'sapling' sized trees (<30 cm dbh). Also their data included few koalas on a geographically restricted range of sites with a restricted range of forest types. This section summarises a wider range of data (Figure 2) including the preliminary data of Jurskis *et al.* (1994) which are thus placed in a clearer context. Some physiological and genetic data from the radio collared koalas are presented. The ecology of koalas at Eden is compared with information from published studies of koalas in other areas.

METHODS

Data are presented for sites where koalas were detected opportunistically (Jurskis *et al.* 1994). Detection rates of koala in regional surveys have been very low (Part A of this paper) and it has not been possible to describe koala habitat by randomly selecting samples representing areas with and without koalas and comparing them. Instead comparisons were made at two levels. One level of comparison was between trees used by koalas (radio locations or scat detections) and surrounding trees not used by koalas at the 'time' of sampling. (This data relates to roost trees which may not necessarily be food trees.) Also, areas of concentrated use within the ranges of radio collared koalas were compared with little used areas and frequencies of koala observations within strata (floristic and historical) were compared with the extent of these strata within the home ranges. At a landform or regional level, the occurrence of incidental records of koala within various strata were compared with the extent of the strata in a broad sense recognising the limitations of the data.

Plots were established around each koala detection tree. These were either trees having koala scats under their crown in the follow up surveys ('centre trees' (Jurskis *et al.* 1994)) or radio location trees for collared koalas (daytime roost trees). The species, diameter and crown class (Florence 1996) of all trees with a diameter at breast height (dbh) of at least 10 cm were recorded.

The plot level comparisons of tree use reported by Jurskis *et al.* (1994) relied on variable radius circular plots including a koala detection tree and its nine nearest neighbours with dbh of at least 30 cm. The plot data were combined into contingency tables with each plot having equal weight irrespective of area. Since koalas were often detected in trees with a dbh less than 30 cm, the method was altered to permit the use of these smaller trees to be analysed. The additional data presented in this report was based on concentric variable radius plots including a koala detection tree and its nine nearest neighbours in each of two size categories: dbh 10-29 cm and dbh 30+ cm. The data from follow up surveys were not weighted for plot area. The data from radio collared koalas were converted to densities per hectare and thus compare the use of tree classes with their average density in the koalas home range.

The Forest Type (FT) according to Forestry Commission of New South Wales (1989) was determined for each location of each radio collared koala by calculating the basal area of each eucalypt species in the plots. Some plots did not fit the description of a single Forest Type and in these cases two Forest Types were nominated and a frequency of 0.5 assigned to each. For those koalas with home ranges (minimum convex polygon) including both logged[5] and unlogged[6] coupes, the areas of coupes were estimated from harvesting plans[7] by dot grid. Estimates of Forest Type areas for Tantawanglo State Forest were obtained from 1:25,000 scale maps of Forest Type prepared using aerial photography interpretation.

Blood samples obtained from radio-collared koalas were assayed for *Chlamydia* by J. Emmins using ELISA (Emmins 1993). Emmins also examined their genetic constitution and compared them with samples from other populations (Emmins *et al.* 1996, Emmins *pers. comm.*). Radio collared koalas were weighed and measurements of their head length were recorded. These were compared with data reported by Melzer and Lamb (1994) including data published by Martin (1983).

1. *DATA ANALYSIS*

The use of trees or strata by koala was compared with the proportion of the same class of tree or stratum in the plots or the home ranges. The G statistic (Zar 1984) was used to identify disproportionate use. Species or strata with a relative exploitation (RE) >1 (White and Kunst 1990) were classified as preferred species or strata provided that the results were statistically significant and expected frequencies were not very low. References to preferences or avoidance in this report mean significantly disproportionate use compared to availability and are not intended to imply specific behaviour by koalas. Importance indices (White and Kunst 1990) were also calculated. The importance index takes account of the abundance of each tree species so that highly preferred trees of very low abundance are ranked lower in importance than preferred trees which are abundant. One koala frequently roosted in rainforest trees. Plots with a rainforest roost tree were analysed separately to those with a eucalypt roost tree.

Radio locations of koalas were mapped on 1:25,000 scale topographic maps. Home range areas were estimated using the McPAAL program (Stuwe and Blohowiak 1985). Minimum Convex Polygons (MCP) were drawn and Harmonic Mean Distance Minima were used to identify the patterns of use within home ranges. Where radio locations were evenly distributed throughout a home range, the 90% Harmonic Mean (HM) isopleth[8] was used to estimate home range size. In other cases the lower valued isopleth which was subjectively judged to best define the core areas of activity (Dixon and Chapman 1980) was used. Home ranges and radio locations are shown for each koala at either 1:25,000 scale or 1:50,000 for larger home ranges.

[5] Affected by integrated logging for sawlogs and pulpwood
[6] Not affected by integrated logging; may have been previously logged for sawlogs or sleepers
[7] Detailed topographic maps at 1:15,000 scale used to plan and carry out logging operations
[8] A line defining a set of locations with minimum dispersion and containing 90% of the koala records.

RESULTS

1. *TREE PREFERENCES*

Koalas were recorded from 16 eucalypts including *Corymbia maculata* and *Angophora floribunda*, as well as six non-eucalypt trees (Appendix 5). Koalas were not recorded from three eucalypts which were present in plots. These were *E. botryoides*, *E. tricarpa* and *C. gummifera*.

(a) *Follow up surveys*

Table 3 summarises the results of the six recent surveys (Part A of this report). Although the data are limited and preferences were not established on three of the sites, the trends are similar to those reported by Jurskis *et al.* (1994).

Table 3. Follow up surveys 1994-96.

Site	No. of plots	Area of [1] regular use (ha)	Species with RE[2] > 1	Comments
Brown Mountain	0	-	-	Both records in mountain gum
Cathcart	6	2	monkey gum	p<0.01
Coolangubra	15	6	monkey gum	p<0.001
Honeymoon Ridge Cpt 2049 Murrah	11	5	woolybutt, silvertop ash	No significant preference
Syndey Murrah	9	5	woolybutt, yertchuk	p<0.01 breeding female sighted
Cpt 2032 Murrah	4	-	monkey gum	No significant preference

[1] Area in which intensive 'asterisk' surveys have detected evidence of koala (Jurskis *et al.* 1994).
[2] Relative exploitation: the ratio of the proportional use of a species to its availability.

The surveys were conducted in three landform units (State Forests of New South Wales 1994) each with its own characteristic assembly of vegetation communities. The Brown Mountain site was on the tablelands in a snow gum-mountain gum vegetation type. The 'Syndey' site was on the coastal hills and valleys landform while the remaining sites were on escarpment and foothills landforms.

The follow up survey data reported by Jurskis *et al.* (1994) were gathered entirely on the escarpment and within the same group of vegetation types as have been sampled at Cathcart and Coolangubra. For this reason the data from Cathcart and Coolangubra were combined with the previously reported data to form a database comprising 96 plots from eight sites. Significant tree preferences were indicated (G=164.51, 10 df, $p<0.001$). *E. cypellocarpa* was clearly a preferred species and being reasonably common, was a very important species (White and Kunst 1990) to koalas (Table 4). *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.

Table 4. Use of tree species by koalas in escarpment forests - follow up survey data.

Species	RE[1]	Importance Index	Adequacy of sampling
Eucalyptus cypellocarpa	2.6	0.764	
Eucalyptus maidenii	1.8	0.095	
Eucalyptus sieberi	0.6	0.075	Well sampled
Eucalyptus globoidea	0.6	0.037	
Eucalyptus obliqua	0.3	0.004	
Eucalyptus fastigata	0.1	0.000	
Eucalyptus bosistoana	5.1	0.013	
Eucalyptus elata	5.1	0.013	Low expected frequencies(<5)
Eucalyptus muelleriana	0.0	0.000	inadequately sampled
Eucalyptus agglomerata	0.0	0.000	

[1] Relative exploitation: the ratio of the proportional use of a species to its availability.

The three remaining sites from which tree use data were collected in follow up surveys occurred on two different landforms. Nevertheless they were in the same geographic area (Figure 2). The sites were also similar in that *E. cypellocarpa* was uncommon and *E. longifolia* was reasonably common. The data from 24 plots on these three sites were grouped for analysis. Significant tree preferences were indicated ($G=24.35$, 11 df, $p<0.025$). The limited data suggested that *E. consideniana* - yertchuk and *E. longifolia* - woolybutt were preferred and important species (White and Kunst 1990) for koalas in the Murrah area (Table 5). *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.

Table 5. Use of tree species by koalas in coastal hills and valleys - follow-up survey data.

Species	RE	Importance Index	Adequacy of sampling
E. consideniana	4.1	0.516	
E. longifolia	1.6	0.201	
Stringybark[1]	1.0	0.018	Well sampled
E. sieberi	0.9	0.113	
E. globoidea	0.5	0.018	
Corymbia gummifera	0.0	0.000	
E. cypellocarpa	5.3	0.095	
Angophora floribunda	1.1	0.020	
E. agglomerata	0.9	0.018	Low expected frequencies (<1.5)
E. muelleriana	0.0	0.000	inadequately sampled
E. smithii	0.0	0.000	
E. tricarpa	0.0	0.000	

[1] May include *E. agglomerata*, *E. globoidea* and *E. muelleriana*.

(b) *Radio-tracking studies*

Eight koalas were tracked for varying periods. These koalas occurred in three separate geographic areas (Table 6, Figure 2).

Table 6. Summary of radio-tracking data available for analysis.

ID	Geographical/landform unit	No. of locations
Ruth		90
Simon	Tantawangalo/Yurammie escarpment	43
Wayne		88
Bob		87
Roberta		45
Robert	Kiah foothills	18
Michelle		16
Allan	Bermagui coastal hills	69

Four of the radio collared koalas lived on the escarpment. Their tree species preferences were compared with those from follow up surveys on the escarpment (Table 7). The koalas in the escarpment forests had a general preference for *E. cypellocarpa* and it was a very important species (White and Kunst 1990) for them (Table 7). *E. sieberi* was not preferred when all trees of at least 10 cm dbh were considered. However, koalas in the escarpment forests made considerable use of *E. sieberi* and some use of the stringybarks *E. globoidea* and *E. muelleriana*. *E. fastigata* was little used.

Table 7. Comparison of tree species preferences of koalas - escarpment forests.

Species	Asterisk surveys RE	Asterisk surveys Import[2]	Ruth RE	Ruth Import	Simon RE	Simon Import	Wayne[1] RE	Wayne[1] Import	Bob RE	Bob Import
E. cypellocarpa	2.6	0.764	1.8	0.544	2.9	0.605	2.1	0.558	3.7	0.734
E. maidenii	1.8	0.095					0.6	0.045		
E. sieberi	0.6	0.075	0.7	0.169	0.8	0.166	1.2	0.205	0.8	0.067
E. globoidea	0.6	0.037	0.6	0.033			0.5	0.052	0.6	0.022
E. obliqua	0.3	0.004					1.0	0.096	0.3	0.003
E. fastigata	0.1	0.000			0.4	0.025			0.3	0.003
E. elata					0.8	0.061			0.6	0.036
E. muelleriana									1.1	0.047

[1] Most plots include only trees of at least 30 cm dbh

[2] Importance Index (White and Kunst 1990)

Three of the radio-collared koalas lived in the foothills (Figure 2) on sites that had some similarities with the follow up survey sites at Murrah. These coastal sites were at relatively low altitudes and *E. sieberi*, *E. longifolia* and *E. globoidea* were fairly common trees on all sites. The limited data from these sites indicated that *E. sieberi* was not preferred but was frequently used and important (White and Kunst 1990) to koalas (Table 8). *E. cypellocarpa* was preferred and important when it was present. *E. longifolia* was preferred and important to some koalas. *E. consideniana* has a very limited distribution near the coast but was a preferred and important species at one site while *C. gummifera* was not used by koalas at that site.

Table 8. Comparison of tree species preferences of koalas - foothills and coastal valleys.

Species	Asterisk surveys RE	Asterisk surveys Import	Roberta RE	Roberta Import	Robert[1] RE	Robert[1] Import	Michelle[1] RE	Michelle[1] Import
E. consideniana	4.1	0.516						
E. cypellocarpa			3.0	0.660	1.9	0.422	1.8	0.768
E. longifolia	1.6	0.201	0.5	0.007	3.4	0.506		
Stringybark	1.0	0.018						
E. sieberi	0.9	0.113	0.8	0.217	0.6	0.179	1.3	0.212
E. globoidea		0.5	0.018		1.3	0.300		
C. gummifera	0.0	0.000						
E. muelleriana			0.7	0.079	0.00	0.000	0.4	0.020
E. agglomerata			0.9	0.027				

[1] Preferences are not statistically significant

(c) *Individual koalas*

The radio-tracking data were analysed separately for each individual koala to highlight any differences in tree preferences amongst koalas of different age or sex. Species and size class preferences as well as preferences for particular tree crown classes (Florence 1996, Appendix 6) were also examined. Average

Stand Tables showing the composition of each koala's home range in terms of trees per hectare by species and size classes are presented in Appendix 7.

(i) *Ruth*

This koala did not use tree species and size classes in proportion to their availability (G=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.

(ii) *Simon*

This koala preferred *E. cypellocarpa* trees of all size classes (G=118.66, 37 df, $p<0.001$). It also preferred intermediate and medium sized *E. sieberi* (50 to 89 cm dbh) but was never found in *E. sieberi* trees less than 30 cm dbh even though trees of this species and size averaged more than one-third of the stand in the koala's range. The koala preferred trees with crown class 4 (G=81.60, 11 df, $p<0.001$). This applied in both logged coupes (G=69.28 11 df, $p<0.001$) and unlogged coupes (G=23.28, 11 df, $p<0.05$). Class 4 indicates a mature tree in the upper canopy with a healthy crown which has been distorted by competition in the past (Appendix 6). This crown class tends to be associated with the intermediate and medium diameter classes. The two variables are probably not independent.

(iii) *Wayne*

Most of the data collected from this koala did not include trees less than 30 cm dbh. Considering only trees over 30 cm dbh, the koala preferred *E. cypellocarpa* and, regardless of species, preferred smaller trees in the range 30 to 69 cm dbh (Jurskis *et al.* 1994).

Only 18 observations of this koala were made after those reported by Jurskis *et al.* (1994). This data was insufficient to demonstrate any preferences. The koala was observed more frequently than expected in *E. cypellocarpa* including sapling sized trees (<30 cm dbh). It occurred less frequently than expected in sapling sized trees of *E. sieberi*. Trees with crown class 9 (subdominant, overtopped trees) were used more frequently than expected. None of these observations were statistically significant.

(iv) *Bob*

This koala preferred *E. cypellocarpa* in all size classes over 30 cm dbh (G=192.78, 40 df $p<0.001$). The koala used *E. cypellocarpa* 'saplings' (dbh <30 cm) in proportion to their availability while it avoided saplings of other eucalypt species. The koala frequently used *E. sieberi* and *E. elata* in size classes above 30 cm dbh. The koala preferred (G=103.18, 11 df, $p<0.001$) trees with a crown class of 4 or 9 (Appendix 4) and made little use of trees with crown class 7 (regrowth trees).

(v) *Roberta*

This koala preferred *E. cypellocarpa* in all size classes greater than 30 cm dbh (G=96.23, 37 df, $p<0.001$). It used smaller trees of this species in proportion to their availability but avoided sapling sized trees of all other species. The koala frequently used *E. sieberi* between 30 and 69 cm dbh.

The koala also had a preference for particular crown classes (G=46.81, 11 df, $p<0.001$). Like most of the other koalas it 'favoured' crown classes 4 and 9 but it also favoured classes 2 and 11 and avoided trees with crown class 7 (Appendix 6). This koala was twice observed in small trees of *Allocasuarina littoralis*.

(vi) Robert

Although this koala was observed relatively frequently in *E. longifolia*, *E. cypellocarpa* and *E. globoidea*, the results were not statistically significant. The koala also made considerable use of *E. sieberi*. The koala was only observed twice in sapling-sized trees both of which were *E. cypellocarpa*. When the data were grouped into size classes including all species combined, the koala had an apparent preference for trees greater than 30 cm dbh especially intermediate sized trees (50 to 69 cm dbh) (G=11.50, 4 df, p<0.025). The koala preferred trees with a crown class of 4 or 9 in unlogged forest (G=25.88, 11 df, p<0.01). In logged forest it was observed more frequently than expected in trees with crown class I but this result was not statistically significant. The data set for this koala was small (18 observations, Table 4).

(vii) Michelle

Except for two small trees just over 30 cm dbh, this juvenile koala was only observed in sapling sized eucalypts (less than 30 cm dbh). Although it used *E. cypellocarpa* more frequently and *E. sieberi* less frequently than expected, the result was not statistically significant. This koala was twice observed in non-eucalypts, once in a small tree of *Elaoecarpus reticulatus* and once in an *Acacia cognata*.

(viii) Allan

This koala preferred (G=95.76, 35 df, p<0.001) intermediate sized (50-70 cm dbh) *Corymbia maculata* and *E. cypellocarpa*. It was never observed in sapling sized (<30 cm dbh) *C. maculata* or *E. muelleriana* even though these trees made up a large proportion of the stocking in its range. The koala preferred the dominant regrowth trees (G=136.60, 11 df, p<0.001) with 64% of observations being in crown class 1.

When the koala roosted in rainforest trees, 82% of the observations were in *Backhousia myrtifolia* (grey myrtle) but this was by far the most common species. The species x size analysis showed a preference (G=41.10, 12 df, p<0.001) for larger trees (>30 cm dbh) of this species and smaller (<30 cm dbh) *Acmena Smithii* (lilly pilly) and *Pittosporum*. Crown classes were not assigned to the rainforest trees as they were typically dense round-crowned trees with high shade tolerance.

2. *ENVIRONMENTAL AND HISTORICAL FACTORS*

(a) Forest Type

Most of the radio collared koalas were observed more frequently in dry (Forestry Commission of New South Wales 1989) than in wet Forest Types (Table 9). Except for 'Brown Mountain' and 'Syndey' (Table 3) and an incidental observation at Wog Mountain, the follow-up surveys and incidental records of koalas occurred in forest types that were sampled in the radio tracking studies. Three Forest Types which were not sampled in the radio-tracking program were snow gum-mountain gum (Brown Mountain), yertchuk (Syndey) and white ash (Wog Mountain). The 23 Forest Types (Forestry Commission of New South Wales 1989) in which koalas have been observed are described in Appendix 8.

The use of Forest Types by the seven radio collared koalas which occurred in the escarpment and foothills landform type was compared to the prevalence of the Forest Types within Tantawangalo State Forest. The comparison suggested that the dry Forest Types particularly the stringybark-gum types received disproportionately high use by the koalas compared with the wet Forest Types (Table 10). Although Forest Type 158 appeared to be relatively unimportant, it mainly occurs on steep escarpments which are difficult to access and have not been well sampled in koala surveys.

Table 9. Occurrences of radio-collared koalas in Forest Types[1]

	Forest Type																	
	Dry									Wet								
Koala	63	112	114	121	123	132	150	152	Total	154	155	156	157	158	165	166	169	Total
Ruth		21	26.5			10.5	1.5	1	60.5		1		2	22.5			-	25.5
Simon		12.5	3				2.5	1	19	6	5		1.5	2		3.5	2	20
Wayne		1	1		1	4	2	1	10	1		1		1				3
Bob		17	14.5		8	8	1.5	7	56	2	5		4.5	5.5	1	7.5	6.5	32
Roberta	3	7	13	1		1			25				10	2			6	18
Robert	1	2	3		2	3	1		12								2	2
Michelle		0.5	5						5.5				3	0.5				3.5
Total	4	61	66	1	11	26.5	8.5	10	188	9	11	1	21	33.5	1	11	16.5	104

63 Woolybutt
112 Silvertop ash
114 Silvertop ash-stringybark
121 Blueleaved stringybark
123 Coastal stringybark
132 Stringybark-gum
150 Messmate
152 Messmate-gum
154 Brown barrel
155 Brown barrel-gum
156 Brown barrel/messmate-ash
157 Yellow stringybark-gum
158 Southern blue gum
165 Gully peppermint
166 River peppermint
169 Yellow stringybark

[1] Where the floristic composition of plots did not fit a single Forest Type, two Forest Types were nominated and a frequency of observation of 0.5 was assigned to each Type

Table 10. Use of Forest Types by koalas compared with prevalence of Forest Types.

	Dry			Wet					
	112	114+123+132	150	152	154	155	156	157	158
Relative frequency koala observ. %	23.6	40.0	3.3	3.9	3.5	4.3	0.4	8.1	13.0
Relative frequency of Forest Type on Tantawangalo SF %	10.2	6.2	1.1	21.4	27.2	12.5	5.6	4.5	11.3
RE	2.31	6.45	3.00	0.18	0.13	0.34	0.07	1.80	1.15
Importance Index	0.154	0.728	0.027	0.002	0.001	0.004	0.000	0.041	0.042

112 Silvertop ash, 114 Silvertop ash-stringybark, 123 Coastal stringybark, 132 Stringybark-gum, 150 Messmate, 152 Messmate-gum, 154 Brown barrel, 155 Brown barrel-gum, 156 Brown barrel/messmate-ash, 157 Yellow stringybark-gum, 158 Southern blue gum

Forest Types 165 and 169 do not occur on Forest Type maps of Tantawangalo State Forest and have been excluded from this comparison. Type 166 only occurred in the plots as one of two overlapping types on steep slopes. However Type 166 as mapped in Tantawangalo State Forest is the characteristic creek bank community (Forestry Commission of New South Wales 1989) so Type 166 was also excluded from the comparison. Types 114, 123 and 132 as mapped on Tantawangalo State Forest are closely related Types which have been combined in the comparison.

Although most observations of radio collared koalas have been in dry forest types, the koala at Bermagui occupied mainly wet sclerophyll forest (Table 11).

Table 11. Forest Types occupied by the koala "Allan".

Forest Type	23	50	63	70	75	157	158	169
Nature	Rainforest	Wet	Dry	Dry-Wet	Wet	Wet	Wet	Wet
No. of observations	4	0.5	2	15	14.5	3	4	1

23 Myrtle, 50 Bangalay, 63 Woolybutt, 70 Spotted gum, 75 Spotted gum-yellow stringybark, 157 Yellow stringybark-gum, 158 Southern blue gum, 169 Yellow stringybark

The floristic composition of each koalas home range (MCP) was described in terms of the relative mean basal area of each eucalypt species recorded in the plots. *E. sieberi* was usually the predominant species in the home range of the radio-collared koalas. The preferred species *E. cypellocarpa* was usually prominent (Table 12). Two other tree species were also prominent. They were *E. globoidea*, especially on the escarpment, and *E. muelleriana*, especially in the foothills and coastal hills.

Table 12. Relative mean basal area (%) by species for each koalas home range.

	Species[1]															
Koala	Sie	Cyp	Mue	Glo	Obl	Mac	Fas	Ela	Lon	Agg	Tri	Mai	Bos	Smi	Bot	Gum
Ruth	40.5	31.8	6.2	15.9	3.2		.6	.4				1.2	2			
Simon	36.0	12.8	8.4	3.2	7.4		21.2	11.0					0.0			
Wayne	14.4	23.8	1.9	27.8	23.1		7.1	1.8					0.2			
Bob	27.9	16.4	14.8	16.7	6.2		5.8	11.6						0.5		
Roberta	30.5	17.7	36.4	1.5	0.7			0.4	8.3	3.5	1.0		0.0			
Robert	23.3	9.9	18.4	29.1	6.4				6.5	2.6	3.9					
Michelle	33.0	27.6	35.7						3.7							
Allan		12.8	23.3	0.1		49.3			9.2		1.2		0.1		3.8	0.1
Average	26	19	18	12	6	6	4	3	3	1	1	0	0	0	0	0

[1] Species codes are as follows: *E. sieberi* (Sie), *E. cypellocarpa* (Cyp), *E. muelleriana* (Mue), *E. globoidea* (Glo), *E. obliqua* (Obl), *E. fastigata* (Fas), *E. elata*, (Ela), *E. agglomerata* (Agg), *E. longifolia* (Lon), *E. tricarpa* (Tri), *E. maidenii* (Mai), *E. bosistoana* (Bos), *E. smithii* (Smi), *C. maculata* (Mac), *E. botryoides* (Bot), *C. gummifera* (Gum).

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.).

Limited data from asterisk surveys at Murrah (Table 5) suggested that, in that area, *E. longifolia* and/or *E. consideniana* may be important components of forests used by koalas.

(b) Logging disturbance

(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 (Figure 10) 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 TSI[9]. 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 (Appendix 7) created by past disturbances.

(iii) Logging Interaction Surveys at Murrah (Part A of this paper) 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) *Wildfire*

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) *Old growth forest*

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 (Figure 3). Home range analyses (see below) did not suggest that koalas preferred less disturbed areas within their ranges.

3. *MOVEMENTS AND HOME RANGES*

The koalas had large home ranges and were mobile (Table 13). Where the Harmonic Mean analyses of home range indicated patchy use of habitat, lower value isopleths were used to define core areas (Dixon and Chapman 1980) (Table 13).

[9] Timber Stand Improvement: ringbarking or felling to waste of unmerchantable trees

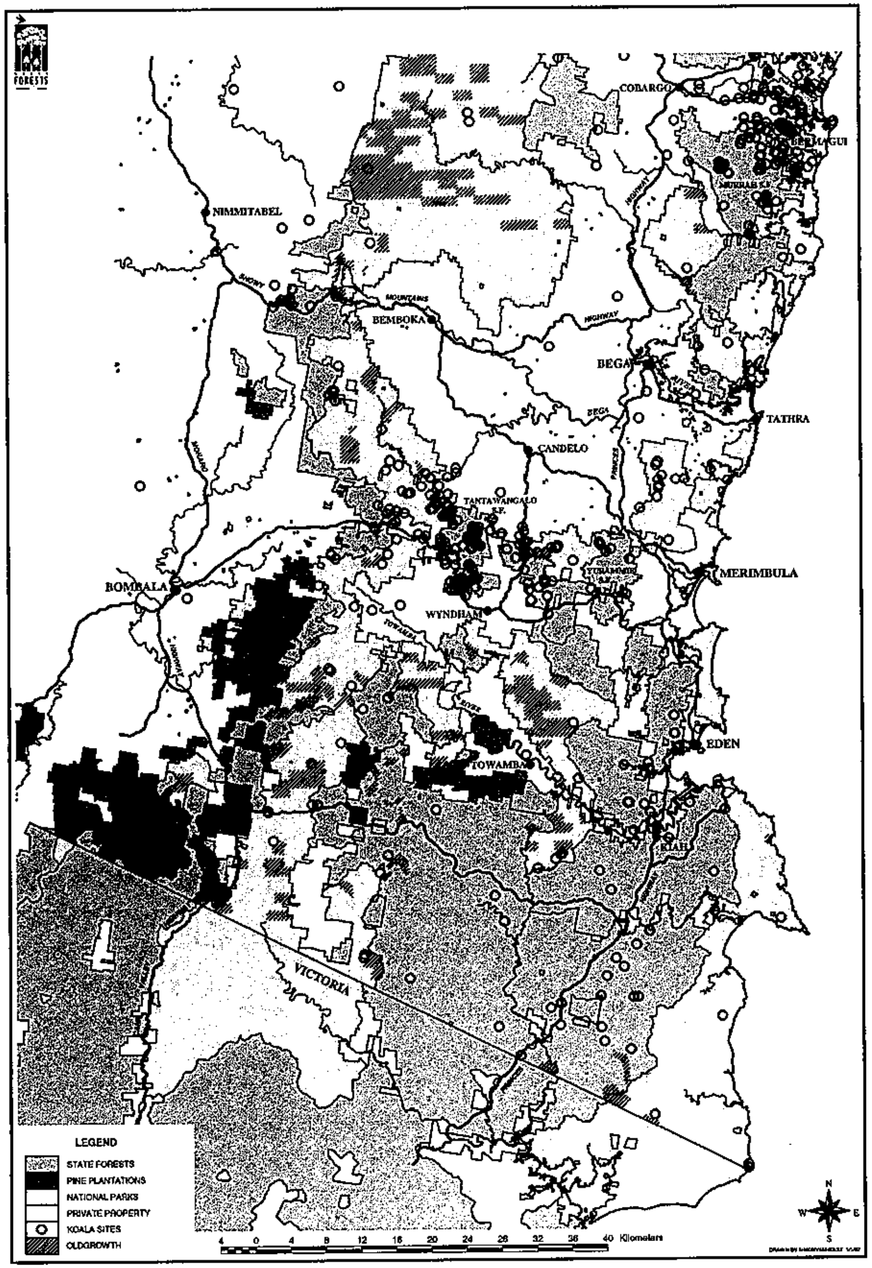

Figure 3. Koala locations and old growth forest at Eden.

Table 13. Movements and home ranges[1] of radio-collared koalas.

Koala	Description	MCP area (ha)	Harmonic mean area (ha)	% locations	Mean minimum distance (m)	Mean daily distance (m)	Maximum overnight movement (m)
Ruth	Mature	67	63	90	70	160	580
Simon	Mature	152	63	60	100	250	560
Wayne	Sub-adult	2063	520	75	130	250	700
Bob	Sub-adult	321	136	90	60	190	500
Roberta	Mature	566	202	50	160	260	1320
Robert	Mature	194	164	90	170	190	300
Allan	Mature	101	38	70	75	280[2]	280[2]

[1] No. of observations is given in Table 6
[2] Only one observation

(a) *Ruth*

This koala had a reasonably symmetrical home range (Figure 4) and its MCP and 90% HM ranges corresponded closely in size and position. Its 90% HM was smaller than its MCP. The 75% HM isopleth was very similar in shape to the 90% isopleth. These features suggest that the koalas resources and activities were fairly evenly dispersed. Twelve trees (13% of observations) were visited by this koala on more than one occasion. Two of these were visited three times and one four times.

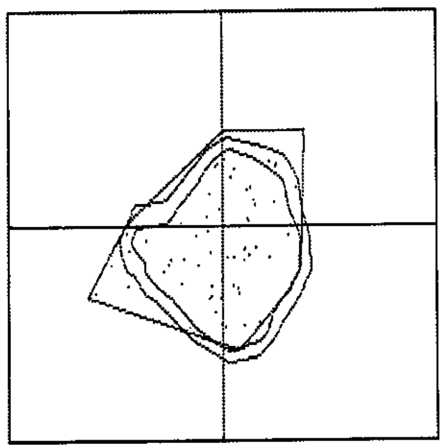

Figure 4. Home range of 'Ruth' MCP and HM 90%, 75% isopleths. 1 km grid. (Scale 1:25,000).

(b) *Simon*

Although the koala had a reasonably symmetrical range and its MCP and 90% HM corresponded fairly well, the 90% HM home range was larger than the MCP suggesting that areas of more frequent use were interspersed with areas of less frequent use (Figure 5). The 60% HM isopleth illustrates a central area of concentrated use with a smaller concentration drawing a 'point' out to the east. There is also a separate small node of concentrated activity to the west. These concentrations of activity are associated with logged coupes (Figure 6).

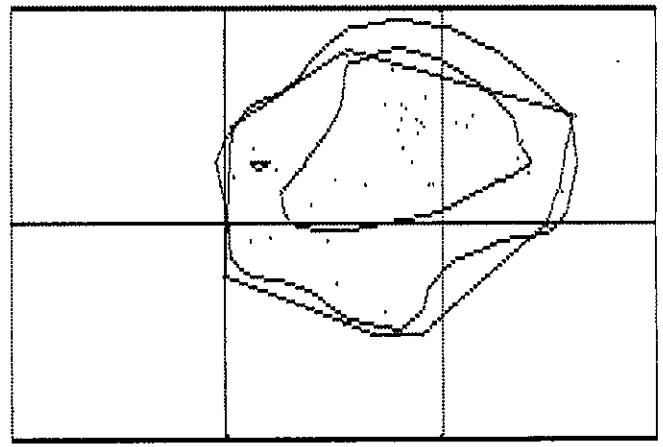

Figure 5. Home range of 'Simon' MCP and HM 90%, 60% isopleths. 1 km grid. (Scale 1:25,000).

Figure 6. Home range of 'Simon' HM 60% isopleth and logged coupes. 1 km grid. (Scale 1:25,000).
Logged coupes ☐ Unlogged coupes ▨

(c) *Wayne*

This koalas MCP and 90% HM were quite different in size and location (Figure 7). The 90% HM isopleth defined a large area of concentrated activity in the north and a smaller area in the south containing only one record. This southern 'node' actually represents the geometric centre (Dixon and Chapman 1980) of a large area of very dispersed activity. The 75% HM area indicates the northern zone of concentrated activity. The koala apparently had a reasonably well established range in the north of its MCP but occasionally ventured more widely.

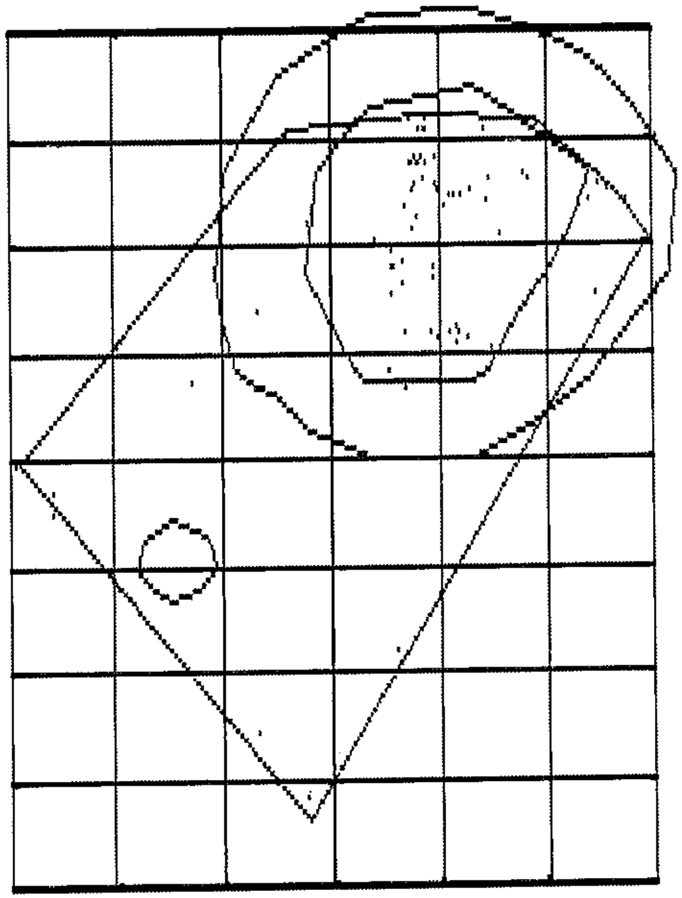

Figure 7. Home range of 'Wayne' MCP and HM 90%, 75% isopleths. 1 km grid. (Scale 1:50,000).

(d) *Bob*

The MCP for this koala was more than twice the size of the 90% HM area (Figure 8). The 90% HM indicated an area of concentrated use in the north of the MCP. All the records outside and to the south of the 90% contour occurred in a short time period after the koala's capture suggesting that the koala was either dispersing from its maternal range or returning from a 'foray' when it was captured. Nine trees (10% of records) were visited twice by this koala.

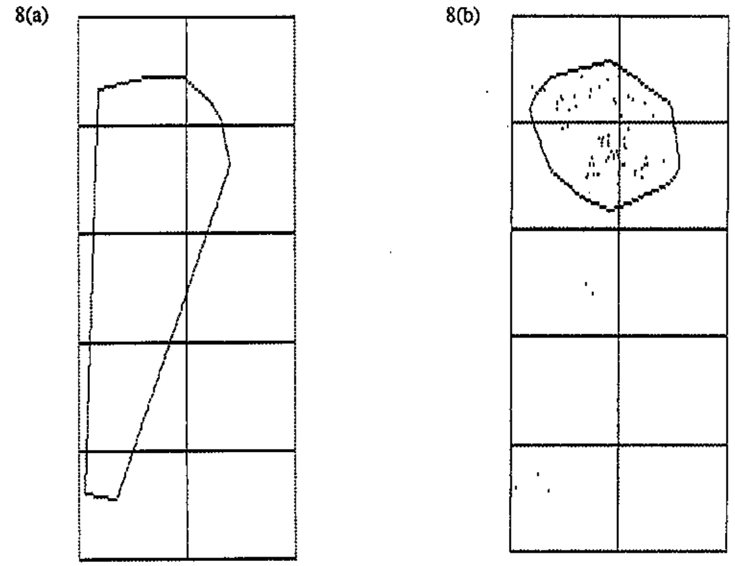

Figure 8. Home range of 'Bob': (a) MCP, (b) HM 90% isopleth. 1 km grids. (Scale 1:50,000).

(e) *Roberta*

The 90% HM isopleth for this koala was substantially bigger (about 20%) than the MCP and there were two clear outliers (consecutive observations) about 1 km outside the isopleth (Figure 9). This indicates patchy use of habitat within the 90% contour as well as a long foray outside. The 75% contour was less symmetrical and highlighted two concentrations of activity in the east and west joined by 'bridges' to the north and south surrounding a little used area (Figure 9). The 50% contour emphasises the two nodes and the northern 'bridge' (Figure 9). The central area contained unlogged forest whilst the nodes were associated with logged coupes. The northern 'bridge' was associated with a ridge that was heavily logged for sleepers many decades ago.

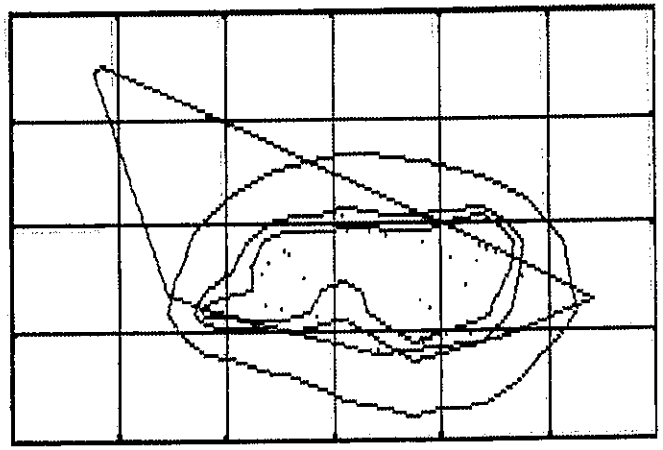

Figure 9. Home range of 'Roberta' MCP and HM 90%, 75%, 50% isopleths. 1 km grid. (Scale 1:50,000)

(f) Robert

Comparison of the MCP and HM 90% isopleth for this koala (Figure 10) suggested patchy use of habitat and the existence of two outliers but the data are too limited to draw any strong conclusions. The 1 km grid is the same in Figures 9 and 10. The western node of 'Roberta's' HM 50% isopleth and the eastern node of 'Roberts' HM 90% isopleth overlap. There was also an overlap in time of these records however it was during the same time period that 'Roberta' made a long foray to the north west (Figure 9) and 'Robert' made a foray to south (Figure 10). We have no evidence of an encounter between these two koalas.

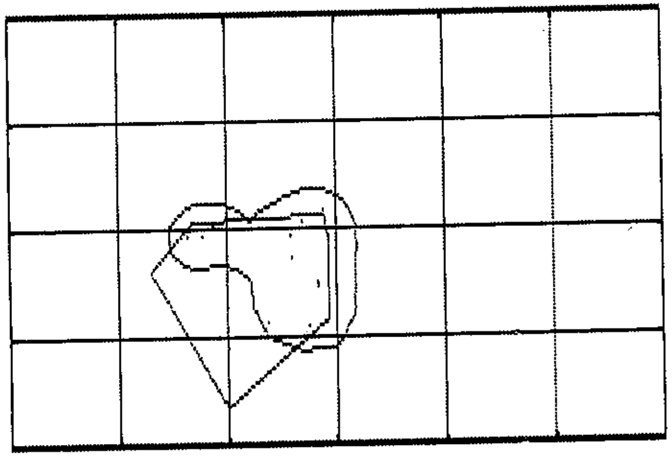

Figure 10. Home range of 'Robert' MCP and HM 90% isopleth. 1 km grid. (Scale 1:50,000).

(g) Allan

The MCP and HM 90% contour are similar for this koala and both have an elongated shape (Figure 11). The HM 70% contour illustrates two nodes of concentrated use within the koalas range. Five trees were visited more than once by this koala. One of the trees was visited three times. Revisited trees occurred in both nodes and one was outside the nodes defined by the 70% isopleth.

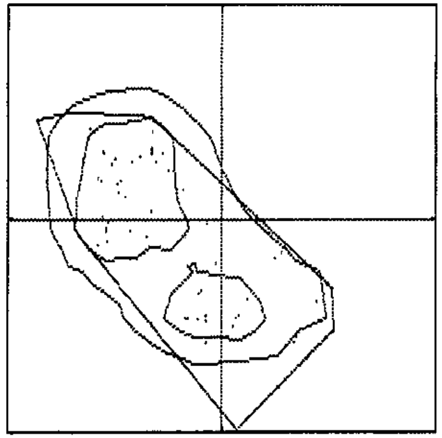

Figure 11. Home range of 'Allan' MCP and HM 90% and 70% isopleths, 1 km grid. (Scale 1:25,000).

When the HM 90% and 70% isopleths were overlaid on a topographic map (Figure 12) it was apparent that the 90% isopleth was bounded by the major road system to the north east, while the minor road system separated the two 70% isopleths. It appears that the koala avoided the roads and/or ridges.

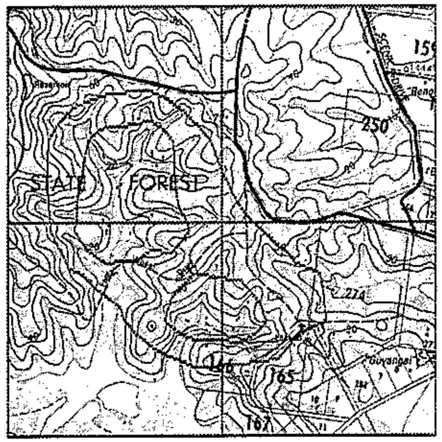

Figure 12. Home range of 'Allan' HM 90% and 70% compared with topography and road system. 1 km grid. (Scale 1:25,000).

(h) Michelle

This juvenile koala was located on 16 occasions. All these locations were within an area of less than 1 ha. This koala visited one tree on two separate occasions.

4. *KOALA BEHAVIOUR*

Excluding females with dependent young, no social interactions were observed between koalas. On one occasion, an adult male and a juvenile female were observed in different positions within the same tree. During surveys (Part A of this report) male koalas responded to playback on many occasions. Responses were usually vocal and from some distance. On one occasion a koala approached a surveyor aggressively on the ground and retreated only when the surveyor fended it off with his torch. Radio-collared koalas did not respond to playback from observers in visual contact except by looking. Attempts to monitor koala behaviour were frustrated by koalas retreating up a tree or fleeing up the nearest tree when they became aware of observers. On a few occasions koalas which had been observed over several hours quickly disappeared after the observers temporarily retreated. On one occasion a juvenile koala retreated to a higher position in a tree via a space created by the mother pushing its body away from the tree trunk. Koalas were rarely observed feeding. One koala appeared to shelter in rainforest trees with dense foliage during adverse weather (very hot, wet or windy conditions).

5. *POPULATION DENSITY*

The average home range size (HM) was 169 ha equivalent to an average density of .006 koalas per ha of forest. From the data presented by State Forests of New South Wales (1994) it was estimated that there are around 210,000 ha of dry forests in the public forest estate. There are also about 101,000 ha of private forests of which roughly half are likely to be dry forests. Assuming that there are few koalas in the wet forests, there is potentially a regional population of 1560 animals. Assuming that 50% of the dry foresis are unoccupied, the possible koala population is in the order of 800 animals. Alternatively, dividing the total area of forest (about 500,000 ha) by the average MCP home range (495 ha) results in an estimated population of about 1000 adult koalas.

6. *PHYSIOLOGY*

The koalas at Eden are *Chlamydia* infected but without clinical expression of disease (Table 14). Their gross morphology appears to be intermediate between Queensland and Victorian koalas (Table 15, Melzer 1994).

Table 14. Physiology of Eden koalas.

ID	Sex	Age	Mean weight (kg)	*Chlamydia*[1]	Head length (mm)	Comments
Ruth	F	Adult	7.0	10	135.5	Bred twice, taken by dingo
Simon	M	Adult	10.3	9	152.5	
Wayne	M	Sub-adult	7.9	9	144.0	Speared by falling branch
Bob	M	Sub-adult	5.5	0	124.9	
Roberta	F	Adult	6.7	5	133.1	Bred two consecutive seasons
Robert	M	Adult	8.4	0	150.9	Lost condition, died in wire grass
Michelle	F	Juvenile	2.0	0		Taken by powerful owl
Allan	M	Adult	7.8	9	148.4	

[1] ELISA test J. Emmins (pers comm.).

Table 15. Comparative physiology of koalas at Eden, Queensland and Victoria.

Provenance	Head length				Weight			
	Female		Male		Female		Male	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Springsure Qld	129	106-145	157	125-194	6.0	2.7-7.6	7.5	4.6-9.7
Brisbane Qld	121	104-134	140	115-151	4.9	3.6-6.4	6.1	4.5-8.7
Victoria (Martin 1983)					7.9	7.0-9.8	11.8	9.5-13.5
Eden NSW[1]	134	133-136	151	148-152	6.9	6.5-7.5	8.5	6.8-10.5

[1] includes only adult koalas

7. *GENETICS*

Emmins *et al.* (1996) compared the genetic diversity of a small sample of Eden koalas with other populations from Gippsland, the Queensland Gold Coast, French Island, the Grampians, Kangaroo Island and the Brisbane Ranges. He found that the genetic diversity of Eden koalas was within the range of natural populations from Victoria (Gippsland) and Queensland and greater than the diversity in the artificial populations (Table 16).

Table 16. Genetic similarity coefficients within populations.

Population[1]	Gipps	Eden	GC	FI	G	Kang	BR
D^2	0.48	0.56	0.63	0.63	0.69	0.71	0.73
Stand dev.	0.13	0.13	0.11	0.18	0.17	0.23	0.03

[1] Codes as follows: Gippsland GIPPS, Gold Coast GC, French Island FI, Grampians G, Kangaroo Island KANG, Brisbane Ranges BR.

[2] Genetic similarity coefficient

Emmins (pers comm.) also examined the genetic relationships between koala populations from Victoria, Gold Coast (Queensland) and Eden. There was a high level of genetic dissimilarity between the natural populations at Eden and the Gold Coast compared to the artificial Victorian populations (Table 17, Figure 13). A moderate level of dissimilarity existed between the two natural populations at Eden and the Gold Coast. There was also a moderate level of dissimilarity between the 'artificial' French Island population and the other two artificial populations. A low level of dissimilarity was apparent between the two mainland Victorian populations (Brisbane Ranges and Grampians) which were 'founded' by French Island koalas (Emmins *et al.* 1996). These relationships are apparent in Figure 13.

Table 17. Genetic dissimilarity coefficients between populations.

	BR	GC	Eden	FI	G
BR	0	.78	.74	.62	.48
GC	.78	0	.66	.72	.74
Eden	.74	.66	0	.73	.73
FI	.62	.72	.73	0	.64
G	.48	.74	.73	.64	0

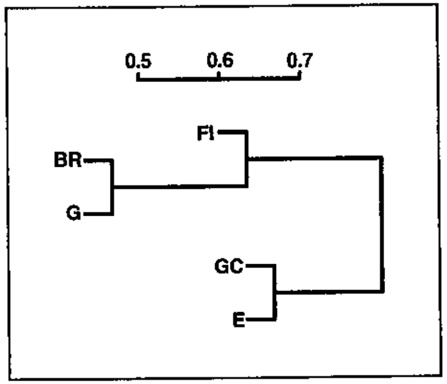

Figure 13. Dendrogram illustrating the relationship between koala populations. The scale bar shows genetic dissimilarity coefficients.

DISCUSSION

1. TREE PREFERENCES

Analyses of tree preferences were based on roost trees. Hindell *et al.* (1985) found that roost trees provided a reliable indication of food trees. Melzer *et al.* (1995) found that day roosting by central Queensland koalas in common tree species provided an indication of their use for fodder but advised caution with respect to less common trees. A requirement for shelter from heat is likely to influence diurnal roosting behaviour by Queensland koalas more than Victorian or Eden koalas. One koala in the current study appeared to shelter from extremes of weather in the dense foliage of small rainforest trees but was only observed feeding in eucalypts. The other koalas were almost invariably observed in common eucalypts. Except for one koala, when roosting in rainforest trees, it is probable that tree preferences in this study provide a good indication of the use of trees for fodder.

There appears to be a general preference for *E. cypellocarpa* when it occurs in the habitat of koalas at Eden (Tables 3, 4, 5, 7, 8). This does not necessarily translate into a preference by koalas for forest containing *E. cypellocarpa* as will be discussed under Forest Type preferences. Some koalas preferred 'sapling' sized trees of *E. cypellocarpa* whilst others used these trees in proportion to their availability. Although analyses of use of tree species by koalas usually indicated that *E. sieberi* and the stringybarks (*E. globoidea, E. muelleriana*) were avoided (Tables 4, 5, 7, 8) this particularly applied to trees less than 30 cm dbh. Many koalas frequently used species such as *E. sieberi* and *E. globoidea* in size classes greater than 30 cm dbh but avoided the large numbers of 'sapling' sized trees of these species in the disturbed multi-aged forests. In the coastal forests there was also evidence suggesting that koalas may prefer *E. consideniana* and *E. longifolia* but only limited data were available. One escarpment tree species - *E. fastigata* and one coastal species - *E. gummifera* appeared to be avoided by koalas.

Apart from the juvenile, the koalas generally preferred small, intermediate and medium sized trees 30-90 cm in diameter rather than saplings or large trees. Although tree diameter and crown class are not independent variables the evidence suggests that each has an intrinsic influence on tree selection by koalas. For example, two koalas preferred logged coupes even though intermediate to medium sized trees were more abundant in the unlogged coupes. This suggests that crown condition rather than tree size was the important factor. On the other hand, some tree species (including rainforest understorey species) were preferred in the small (30-50 cm dbh) class but avoided in the sapling (<30 cm dbh) size class. This size discrimination by koalas may be related to the 'mechanics' of climbing. The juvenile koala 'Michelle' did not discriminate against 'sapling' sized trees. It may be that koalas climb most efficiently when the diameter of the tree is close to the combined 'reach' of the forelegs and are at a mechanical disadvantage when the tree diameter is much less than the koalas' reach.

There was a general tendency amongst the koalas to use trees with a crown class of 4 or 9 (Florence 1996, Appendix 6). These are trees having distorted crowns which have suffered competition from other trees. One koala also preferred dominant trees (Class 2) and another exclusively preferred dominant trees (Class 1). This koala lived almost entirely in regrowth forest with trees about 80 years old or younger. It is likely that the utility of the various crown classes to koalas varies with the age and structure of the forest containing them. In the younger logging regrowth forests, two koalas 'Simon' and 'Roberta' preferred the larger and older retained trees rather than the new 'sapling' sized trees. However, even though both logged and unlogged coupes occurred in their ranges, they preferred the logged coupes. This evidence suggests that crown exposure and freedom from competition in the retained trees enhanced their value to the koalas. Similarly in the older regrowth forest occupied by the koala 'Allan', the preferred dominant (Class 1) trees were above the general canopy level. It may be possible that the koalas used the larger emergent trees mainly for roosting and fed mainly on the smaller regrowth trees but there was no evidence of this. Furthermore the koala 'Allan' frequently used the rainforest understorey tree *Backhousia myrtifolia* for roosting but did not prefer this species amongst those 'available'. The koala was never observed feeding in the rainforest species. It appears more likely that this koala fed in the emergent eucalypts but utilised the dense crowned rainforest understorey trees in the gullies for shelter during adverse weather.

Many studies have compared preferred eucalypt foliage with less palatable or rejected browse. Koalas prefer young leaves rather than mature leaves and there is a threshhold of minimum moisture content and nitrogen content which determines preferred foliage (Pahl and Hume 1990). The threshhold moisture content may vary seasonally (Melzer 1994). There is also a threshhold level of essential oils and preferred species have more volatile oils but less heavy oils than other species (Hume 1995). Preferred foliage has higher concentrations of crude protein, phosphorus and potassium and lower concentrations of fibre than rejected foliage (Ullrey *et al.* 1981). Preferred tree species have more simple sugars in their leaves and less complex sugars than less preferred species (Osawa 1993). In the studies mentioned above, there were at least nineteen different eucalypt species which were preferred by koalas at some stage. Preferences varied over time. At any given time, within a single tree species, some leaf collections were consumed and some rejected (Ullrey *et al.* 1981). It is apparent that species alone does not determine food preferences for koalas and many different species may be eaten in various situations. Apart from food, other requirements, such as shelter (Melzer 1994) or mechanical advantage (see above) may influence koalas' use of trees. In a national koala survey, koalas were recorded in 69 eucalypt species and nearly 30 non-eucalypts (Phillips 1990).

Several authors have listed tree species in which koalas are frequently or occasionally observed, *eg* Warneke (1978), Pahl *et al.* (1990) and Reed *et al.* (1990). *E. cypellocarpa* was not generally recognised as a preferred species in New South Wales. Reed *et al.* (1990) did not list *E. cypellocarpa* as a tree utilised by koalas although Pahl *et al.* (1990) recognised that it was occasionally utilised in Victoria. Pahl and Hume (1990) found that young foliage of *E. cypellocarpa* ranked highly in feeding trials. Lee *et al.* (1990) found that some translocated koalas frequented trees of *E. cypellocarpa* (formerly *E. goniocalyx*) at Lysterfield in Victoria. Warneke (1978) identified *E. goniocalyx* (now *E. cypellocarpa)* as a prime food species in Victoria. Allen (1992) suggested that, on the basis of scratchmarks, *E. cypellocarpa* is an important tree for koalas at Eden and large trees are more important than small trees. Jurskis *et al.* (1994) argued that most clawmarks on trees at Eden are not made by koalas, but using radio tracking and koala scat evidence they found that *E. cypellocarpa* was a preferred species at Eden. The current study confirms that finding.

Hindell and Lee (1987) found that koalas preferred larger trees but that species preference was more important. Their derived data regarding tree size cannot be directly compared with the current data (Jurskis *et al.* 1994). Jurskis *et al.* (1994) did not find any general preference by koalas at Eden for a particular size class of tree. However, their conclusions regarding tree species and size preferences suffered from a lack of data on trees under 30 cm dbh. The additional data presented in the current study clarified the situation where koalas at Eden generally avoided trees under 30 cm dbh, except for *E. cypellocarpa*, and preferred *E. cypellocarpa* in sizes over 30 cm dbh. Other species such as *E. sieberi* and the stringybarks were frequently used in pole sized and larger trees. The size preferences may be related to the 'mechanics' of climbing since the juvenile koala did not avoid 'sapling' sized trees. We are unaware of any other studies concerning koalas' use of trees according to the relative age and dominance of their crowns.

White and Kunst (1990) found that seven out of twelve eucalypt species on their study site were preferred by koalas. They suggested that the importance of a few tree species to koalas was overstated. Although Hindell and Lee (1987) found that high koala densities were associated with stands dominated by *E. viminalis*, Hindell and Lee (1988) found that most individual koalas in the same area did not show a species preference. Of the koalas which showed a species preference, half preferred species other than *E. viminalis*. Preferences were apparent only where the preferred species was in low abundance (Hindell and Lee 1988). Melzer (1994) found that koala densities were correlated with the relative basal area of preferred species

but not with their absolute basal area. Thus floristics may indicate optimal environments for koalas but the absolute quantity of 'preferred species' may be less important. Melzer (1994) found that the absolute densities and basal areas of non-preferred species were negatively correlated with koala densities. This reinforces the importance of environment and the indirect role of species as indicators of environment. The current study showed preferences of koalas for tree species, size and crown condition. Both preferred trees and koalas were in low abundance in the Eden forests. The contrasts between high and low density populations suggest that in optimal environments most trees can sustain koalas whereas in suboptimal environments fewer trees can sustain koalas.

In the suboptimal environment, the physiology of individual trees probably determines their ability to sustain koalas. Factors such as species, age, size and crown condition influence the physiological processes in the trees which are ultimately expressed as nutritional quality and palatability to koalas. For example, the observed preferences of koalas for various crown classes may be related to the physiology of crown expansion or crown reconstruction. Young foliage and epicormic foliage produced after defoliation have been shown to have enhanced nutritional status for insects compared to mature foliage (Landsberg 1990). Leaf age in an actively expanding 'pole' crown will be lower than in a mature tree whose height and crown spread is changing very little (Jacobs 1955). Amongst mature crowns, those which are responding to defoliation by insects or as a result of competition will have enhanced nutritional status as a consequence of both young age and a higher proportion of epicomic shoots (Landsberg 1990). This is particularly true of more shade tolerant species such as *E. cypellocarpa* (per. obs. of the authors).

2. *FOREST TYPE PREFERENCES*

Koalas appear to be associated with drier Forest Types. In the escarpment forests at Eden they are particularly associated with dry forests containing *E. cypellocarpa*. Six of the radio collared koalas were observed more frequently in dry sclerophyll than in wet sclerophyll forest (Table 9) even though the wet sclerophyll forest types are more prevalent in the escarpment forests than the dry types (Table 10). *E. sieberi* which is a species characteristic of dry sclerophyll forest was the most common species in the areas used by seven radio collared koalas (Table 12). *E. cypellocarpa* was the next most common species in the koalas habitat. Although this species is normally associated with wet sclerophyll forest, particularly Forest Types 157 and 158 (Forestry Commission of New South Wales 1989) (Appendix 8), this was not the typical situation in the current study (Tables 10, 12). The koalas were frequently located in the drier Types 112, 114, 123 and 132 albeit with a substantial component of *E. cypellocarpa*. Another species characteristic of wet sclerophyll forest occurred within the home ranges of the koalas in the escarpment forests (Table 12). This species, *E. fastigata*, was little used by the koalas (Table 7) in marked contrast to its preferential use by greater gliders (Kavanagh and Lambert 1990, Jurskis *et al.* 1994).

On the other hand, the koala 'Allan' at Bermagui was more frequently located in wet sclerophyll forest or rainforest. However there were two factors particular to the range of this koala. One was that the forest was composed almost entirely of advanced regrowth trees up to approximately 80 years old. The other factor was the relatively low relief. The difference between the highest and lowest altitude within this koala's range was about 75 m and the highest nearby feature was only 100 m asl. Thus even though it was in wet sclerophyll forest with a rainforest understorey the koala was often located in trees with relatively exposed or 'emergent' crowns.

Phillips (1990) stated that koalas prefer the more open forests and woodlands and are less common in forests where the tree canopy is continuous or closed. Wet forests are unsuitable habitat according to CSIRO (1996). Jurskis *et al.* (1994) found virtually no overlap between locations at which koalas had been recorded and koala habitat predicted by Norton and Saxon (1993) on the assumption that koalas required wetter areas having large upslope catchments. Melzer (1994) found higher koala densities in woodlands than in open forests and high densities were correlated with low values of foliage projective cover. In the current study, apart from the koala living in regrowth forest at Bermagui, only one koala was observed more frequently in wet than in dry Forest Types (Table 9). All except one of these observations of 'Simon' in wet Forest Types were made either in recently logged coupes or in an area that had been heavily logged about 50 years ago. Although Kavanagh *et al.* (1995) reported an association of koalas with wet sclerophyll forest on the north coast of New South Wales, koalas in their study were strongly associated with forests having a long history of logging and with plantations. These forests contained few old hollow bearing trees (Kavanagh *et al.* 1995) and were essentially regrowth forests. Their survey was restricted to public forests and did not sample the private lands which are likely to contain most of the remaining optimal habitat for koalas (CSIRO 1996, Jurskis 1996). Limited sampling of the better dry forest and woodland habitats as well as an association between the 'independent' variables of Forest Type and logging history may explain the apparent association reported by Kavanagh *et al.* (1995) of koalas with wetter forests. Jurskis *et al.* (1994) found that one koala preferred dry forest when its pattern of activity was compared with the mapped Forest Types in its home range (MCP). Lunney *et al.* (1997) indicated that particular dry Forest Types were preferred by koalas at Eden. The accumulated evidence suggests that koalas are normally associated with woodlands and dry forests but are also associated with disturbed forests in moist situations.

3. *LOGGING DISTURBANCE*

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). Two adult koalas, living in mosaics of logged and unlogged forest preferred the logged coupes. Another koala lived almost entirely in logged and TSId forest. The logging interaction surveys at Murrah showed that koalas were using areas which had been recently disturbed by intensive logging and their densities were similar to those in nearby National Parks and Wildlife Service reserves. Monitoring habitat use by koalas in this mosaic of logged and unlogged forest by radio-tracking would complement this survey work. There have been very few records of koalas from areas containing old growth forests at Eden.

The main concentrations of koala records near Eden (Figure 1) are associated with private lands and/or forests that have been heavily logged or even cleared in the past (Jurskis *et al.* 1994). Although Richards *et al.* (1990) stated that the koala is an occupant of mature forest and is likely to be detrimentally affected by integrated logging, their statement was supported by a single reference. In this reference, Reed and Lunney (1990) reported that koalas in the Clarence Valley near Grafton occurred outside reserves near the edge of the valley. They were mainly in semi cleared grazing land and regrowth forests. In two discussion papers, Norton and May (1993) stated that the koala is threatened with extinction in New South Wales due to integrated logging and Allen (1996) stated that there is a widespread belief that forestry practices degrade koala habitat. He suggested that koala populations in State forests are endangered.

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. In younger regrowth stands, this does not appear to be related to any preference of koalas for younger 'sapling' sized trees (<30cm dbh). Although it is possible that there were differences in the koalas' feeding and roosting habits in these younger stands which we failed to detect, it seems likely that most regenerating trees in logged forests may not be suitable for use by adult koalas until they reach 'pole' size (>30 cm dbh). On the other hand, the value of retained trees may be enhanced soon after logging. We did not detect any appreciable use of wet forests by koalas except in regrowth forests resulting from past logging disturbance. We suspect that effects of historical factors such as logging disturbance on forage quality for koalas outweigh other environmental factors and allow koalas to extend their range into environments which would otherwise be unsuitable.

4. *WILDFIRE*

Severe fires are likely to have at least a short term detrimental impact on koala populations (Jurskis *et al.* 1994). The home ranges of seven of the radio collared koalas had been affected in the past by intense fires and this was apparent in the high frequencies of 'sapling' sized regrowth trees in each koala's range (Appendix 7). The home range of the other koala, 'Allan', also contained a high stocking of 'sapling' sized regrowth trees but in this case it was a result of logging and TSI rather than fire.

There was no evidence that the koalas favoured less disturbed areas within their ranges. In fact two of the koalas preferred areas disturbed by logging rather than less disturbed areas. Although there is anecdotal evidence of longer term localised declines in koala populations following the 1952 fires at Eden (Jurskis *et al.* 1994, Reed and Lunney 1990) this evidence relates to koalas in the vicinity of small settlements and private holdings. For example Veness (1990) stated that "we had koalas down near our house before the '52 fires". There is evidence of rapid recovery of koala populations in public forests that have been decimated by wildfire (*eg* Tilley and Uebel 1990, O'Brien 1995). There are at least two possible explanations for the reported longer term declines in koala populations following wildfires. One is that some settlements were abandoned and reduced human activity led to a reduction in encounters between humans and koalas whilst the recent development of hobby farms and rural residential allotments has reversed this trend. For example, Veness (1990) stated that the 1952 fire "finished Nullica as a settlement at the time, although now people have moved back out there and built new homes". Another explanation is that the remnant vegetation around settlements affected by severe fires was cleared to prevent recurrence of the problem. This is quite likely in view of the trauma experienced. At Nullica in 1952, for example, 13 out of 14 houses were destroyed (Veness 1990) as well as all the poultry, orchards and fences (Bobbin 1989).

5. *OLD GROWTH FOREST*

Allen (1992) suggested that large trees and undisturbed forests may be important to koalas. In two hypothetical studies, Norton and Saxon (1993) suggested that logging could cause the regional extinction of koalas and Norton and Neave (1996) suggested that koala habitats in forests only occur below a critical threshold of disturbance. On the other hand Martin (1985) studied a high density koala population in a 30 year old regrowth forest and Gordon *et al.* (1990) found higher densities of koalas in regrowth bimble box than in mature woodlands of the same species. Gall (1989) studied a dense koala population in a small area containing remnant trees within a 15 year-old plantation.

Although there is little old growth forest at Eden there is no evidence that koalas in the region are associated with old growth forest. Three radio-tracked koalas lived in mosaics of logged and unlogged forest whilst the other five lived in forests with a preponderance of younger trees initiated by wildfire or logging. Most koala records from the region are concentrated in areas containing virtually no old growth forest.

6. *MOVEMENTS AND HOME RANGES*

The average overnight distances travelled by the radio-collared koalas (Table 13) was comparable with data reported by Pieters and Woodall (1996) (Table 18), although the average movement of females at Eden was higher. These data were based on only two koalas, one of which had a large home range and a patchy distribution of activity (Table 13, Figure 9).

Table 18. Comparison of average overnight movements (metres), radio-collared koalas.

Location	Male koalas	Female koalas	Author
Eden	230	210	This study
Gold Coast	274	105	Pieters and Woodall (1996)
Ballarat (Urban)	207	71	Hull (1985)[1]
French Island	68	34	Mitchell (1990)

[1] Cited by Pieters and Woodall (1996)

The female koala 'Roberta' made a long foray (over 3 km) (Figure 9) 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.

7. *POPULATION DENSITY AND REGIONAL DISTRIBUTION*

The density of koala populations at Eden based on the average of the core HM home ranges (Table 13) is one koala per 169 ha or 0.006 koalas per hectare. This is comparable with the lowest density reported in the literature (Table 19) (Melzer and Lamb 1994). Melzer and Lamb (1994) suggested that viable, low density populations of koalas may occupy what had previously been regarded as "poor quality habitat". They considered that such habitat should be seen as low carrying capacity rather than poor quality habitat. Jurskis (1996) suggested that carrying capacity for koalas will vary with environment and history and that koala management should be framed in the context of variable carrying capacity. White and Kunst (1990) noted that koalas can successfully breed at low densities and that low density populations were not under greater stress than higher density populations. They suggested that low density habitat should not be regarded as suboptimal.

Table 19. Density of koala populations studied in Australia.

Location	Density[1] (koalas/ha)	Author
French Island	7.5	Mitchell and Martin 1990
Lismore, northern NSW	4	Gall (1980)
Springsure, central Queensland	1.5	Gordon *et al.* (1990)
Brisbane Ranges Victoria	1.2	Hindell (1984)
Oakey, southern Queensland	1.1	Gordon *et al.* (1990)
Gold Coast	0.4	White and Kunst (1990)
Springsure, central Queensland	0.2	Melzer and Lamb (1994)
Springsure, central Queensland	0.01	Melzer and Lamb (1994)
Capella, central Queensland	0.005	Melzer and Lamb (1994)
Eden	0.006	This study

[1] median values where ranges were given

Phillips and Callaghan (1995) associated breeding populations of koalas or "socially stable aggregations" of koalas with dense populations. They suggested that areas where a high proportion (70%) of trees did not have koala faecal pellets under them were indicative of unsuitable habitat. The current study did not produce any evidence of koalas or their faecal pellets occurring at the densities which Phillips and Callaghan (1995) associated with breeding populations. However the evidence indicates that koalas at Eden have been breeding and sustaining a low density population for nearly a century. Low density populations occur in many areas in Queensland (Table 19).

High density koala populations have not been recorded in the Eden area since the first decade of this century (Lunney and Leary 1988). According to Lunney and Leary (1988), the permanent decline of koala populations in the area early this century was a result of the "irrevocable" loss of valley habitat in its conversion to farmland. Koala numbers have been constantly low at Eden over the last 40 years (Lunney *et al.* 1997). It is apparent that the formerly dense populations will not return unless the valley habitat is restored.

Koalas in forests occur at low densities presumably as a result of dispersed food resources. The koalas are mobile and have been observed moving long distances over a short time. Their bellows carry over considerable distances at night especially under still and humid conditions (Mitchell 1990). Bellows may be audible over 2 km (pers. obs. of the authors). Thus communication within low density populations is quite feasible. A female koala was observed moving 2.6 km, probably to mate, before returning to its home range (Lee *et al.* 1990). Breeding populations occur at very low densities in forest habitats at Eden. The current study supports the existence of robust, low density koala populations.

Although Lunney *et al.* (1997) stated that most of the National Parks and Wildlife Service lands at Eden have never held koalas, 8% of their reported koala localities were on National Parks and Wildlife Service lands. Many of the locality records were associated with surveys by Community Groups (Lunney *et al.* 1997) and State Forests of New South Wales (see above). Conclusions from desk top surveys can be biased by visitation rates (Lunney *et al.* 1997). Since few field surveys have been conducted in National Parks and Wildlife Service lands and visitation in the majority of these lands is limited by a lack of access, it is probable that the survey results of Lunney *et al.* (1997) understate the distribution of koalas on National Parks and Wildlife Service lands. Although Lunney *et al.* (1997) stated that private land is not a major reservoir of koalas across most of the region, most private land is cleared. Thirty-eight percent of their koala localities were from private land even though it contains only twenty percent of the region's forests. This suggests that they may have understated the importance of private land. The koala field survey and research effort in State forests has been relatively large compared with that in other lands at Eden.

The potential koala population at Eden is probably between 800 and 1600 animals (see above) but there is no reason to suspect that it is an isolated population. The forests extend southward across the State border into Victoria and north to the Hunter River in a more or less continuous belt. The survey records of Reed *et al.* (1990) show that in the two State-wide koala surveys prior to 1986, there were virtually no records in the Eden area. The concentration of records in the Eden area from the 1986-87 survey was most probably a consequence of the concentration of wildlife survey effort associated with forestry developments at Eden. The lack of records in all three surveys between about Numeralla and Nowra is closely associated with the Deua and Ettrema Wilderness Areas. A lack of records in that area would be expected given the lack of access and visitation. However it is probable that low density koala populations extend right through the escarpment forests. Isolated records from the vicinity of Wadbilliga National Park (Lunney *et al.* 1997, Figure 1) support this expectation. The low frequency of observations of koalas in multiple use forests with considerable infrastructure and human activity suggests that low density populations in less accessible forests will not be detected without very intensive survey efforts.

8. *PHYSIOLOGY AND GENETICS*

Koalas at Eden are morphologically within the range of variation of other populations in eastern Australia. Their genetic diversity is similar to other natural populations (Emmins *et al.* 1996). Saxon and Shepherd (1992) suggested that the Eden koala population may serve as a genetic "reserve" vital to the future management of koalas in south-eastern Australia. Houlden (1995) found that Victorian koala populations were genetically similar to each other while some northern New South Wales and Queensland populations were considerably more divergent from each other and formed a separate branch on the dendrogram from the Victorian 'cluster'. The Eden koalas, like the northern New South Wales koalas, are quite distinct from the Gold Coast koalas as well as the Victorian koalas (Figure 13) (Emmins pers. comm.). The value of the Eden population as a genetic 'resource' would appear to be similar to the values of all the other natural populations that have so far been studied.

9. *MORTALITY*

Lee and Martin (1988) listed aborigines, dingoes and powerful owls as natural predators of koalas. They also suggested that bush fires and drought were likely causes of mortality. We recorded predation by a dingo and by a powerful owl. The koala taken by the owl was over 2 kg (Table 14) whereas Lee and Martin (1988) suggested that only young koalas weighing less than 1 kg would be taken by powerful owls. The anecdotal evidence indicates that bushfires have taken their toll of koalas at Eden (Reed and Lunney 1990, Veness 1990, Bobbin 1989). Despite the speculations of Reed and Lunney (1990) that drought may have precipitated the final decline of koalas in the Bega Valley, observers at the time attributed it to disease (Lunney and Leary 1988). Lunney and Leary (1988) identified loss of habitat to farmland as the primary cause of the permanent loss of koalas from the Bega Valley. Drought is not listed as injurious agent in the forests at Eden by the Forestry Commission of New South Wales (1982) nor is it discussed as a factor affecting forest health by State Forests (1994). Wilting was associated with loss of koalas during drought in Queensland (Gordon *et al.* 1988). General wilting of forest trees due to drought has not, to our knowledge, been observed at Eden. Thus it is unlikely that drought would be a significant contributor to mortality of koalas at Eden. Other causes of koala mortality observed at Eden have been accidental trauma (one koala was speared by a falling branch) and wasting. The death of one koala may have been precipitated by a cold snap and entanglement in wire grass (pers obs of the Authors).

10. *IMPLICATIONS FOR KOALA CONSERVATION AT EDEN*

Forests appear to have a lower carrying capacity for koalas than woodlands. Nevertheless koalas are able to use the apparently limited and dispersed resources to breed in forests and possibly to take advantage of opportunities that become available as habitat recovers or improves following disturbance such as clearing, wildfire or logging. In State forests at Eden great efforts are made to avoid disturbing koalas and their habitat (Ridley 1993, Jurskis *et al.* 1994). At a landscape scale, current forest management practices including logging and hazard reduction burning are likely to maintain or improve (CSIRO 1996) the carrying capacity of the forests for koalas. Forestry operations have been the main impetus for koala survey and research at Eden. Nearly all the new records of koalas which have accumulated since the preparation of the report by Jurskis *et al.* (1994) have been in the Bermagui and Murrah area (Figure 1). These records and data have resulted mainly from surveys by State Forests staff including prelogging surveys, follow up surveys in proposed logging areas and logging interaction surveys. State Forests staff have also detected several koalas in National Parks and Wildlife Service tenures with limited survey effort. It is likely that many more records would be obtained from National Parks and Wildlife Service lands and private property with additional survey effort. The South East Forest Conservation Council (SEFCC) is a community group which has carried out surveys, mainly within State forests, in the Tantawanglo-Yurammie and Bermagui-Murrah areas. These surveys are ongoing and no results have yet been published.

State Forests' radio-tracking studies have helped to dispel some of the 'mystery' surrounding koalas at Eden. These low density populations operate similarly to the high density, well studied populations albeit on a larger scale. The koalas have established home ranges even though sub-adult males have been observed to make forays over large areas. Overlap in the home ranges of two adult koalas was observed. Even though two adult females had large home ranges they were each observed to produce young in consecutive seasons.

Although the home ranges of the studied koalas were relatively large, many had nodes of concentrated activity and other areas which were infrequently used. These patchy activity patterns increase the likelihood that intensive surveys will detect evidence of koala prior to proposed logging operations and allow the proposals to be modified so as to avoid disturbance to koalas (Jurskis *et al.* 1994, Ridley 1993). The patchy use of home ranges may also explain why some follow up 'asterisk' surveys have defined relatively small (Table 3) 'areas of regular use' (Jurskis *et al.* 1994).

It is apparent, however, that many of the suggestions of the expert workshop (Introduction, Appendix 1) were based on an assumption that high density koala populations, such as have mainly been studied elsewhere, occur at Eden. This does not appear to be the case and therefore many of the suggestions should be re-examined. For example:

- Koala autecology has been extensively researched in other areas. Studies at Eden have not suggested any unique features. A study focusing on populations is merely a study focusing on many individuals and, in a low density population, these individuals will be spread over a large area. Studying the socioecology of a solitary animal species (Martin 1983) in a low density population is difficult and unproductive if not impossible. No social interactions between koalas except for maternal and juvenile animals, were observed in this study. It is reasonable to assume that social interactions will be fewer in a low density population.

- Replication of autecological studies would suffer from the difficulties mentioned above. The limited information in this report was obtained across a reasonably wide environmental and geographic range. It did not suggest any unique factors which have not been studied elsewhere.

- More wide-spread community support would be needed for further trials using dogs in koala surveys to occur.

- Scat-based surveys appear to be the only reliable method apart from radio-tracking for estimating fine scale habitat use of koalas in low density populations.

- A stratified regional survey for koalas is still logistically problematical. Although improved playback methods and appropriate timing may increase the detection rate of a regional survey, recorded frequencies are likely to be so low as to allow comparisons between very broad strata only. The incidental records already available give a broad, landscape scale overview of koala distribution. Lack of access would hinder intensive survey of those areas which have had negligible survey effort or visitation in the past such as Wadbilliga National Park.

- The likely koala population density and size at Eden will prohibit statistically unequivocal testing of clear hypotheses on logging effects. However there appears to be sufficient existing empirical evidence that logging does not pose a long-term threat to koala populations (the current study, Kavanagh *et al.* 1995, Braithwaite 1996, unpubl.[10]). Recognising that very conservative management is applied to logging operations on State forests at Eden to avoid disturbance to koalas or their habitat, there is virtually no risk that koala populations will be adversely affected. If and when logging effects studies are carried out elsewhere, in forests with higher densities of koalas, it may be possible to reduce the level of 'protection' afforded to koalas at Eden and possibly increase the long-term carrying capacity of State forests for koalas.

[10] Braithwaite, L.W. (1996). State Forests of New South Wales Pine Creek State Forest. Draft Koala Literature Review. CSIRO Division of Wildlife and Ecology Canberra, ACT.

- Forestry operations have facilitated koala survey work on State forests outside moratorium areas. Survey work in National Parks and Wildlife Service tenures has been limited by a lack of access and a lack of committed resources. Although the SEFCC may encourage a change of attitude (Allen 1996), community interest in surveying private lands has not been apparent. A stratified regional koala survey using playback may be feasible if these problems can be overcome.

- It would be desirable to involve community groups and academia in koala surveys and research, particularly in a stratified regional survey of all land tenures.

- Experimental manipulations of koala populations and habitat in the region are constrained by low population densities rather than monitoring methods.

- An independent koala research committee was formed in June 1995.

11. FUTURE RESEARCH

The main avenue available to State Forests to gather further information relevant to management of forests for koalas at Eden is to monitor interactions between logging and koalas using radio-tracking. Opportunities for such monitoring may be limited to Murrah State Forest in the short term.

It would be interesting to investigate a possible physiological basis for tree preferences by comparing palatability and nutritional quality of foliage to koalas between trees of different ages, crown types and environments within single species. 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.

The SEFCC intends to conduct stratified sub-regional surveys for koala scats in the Tantawanglo-Yurramie and Bermagui-Murrah areas (Allen 1996). These surveys are likely to be relatively inefficient (Part A of this report). A stratified regional koala playback survey involving academia and the community and covering all land tenures might help to more clearly define the regional distribution of koalas. It may also confirm that the results presented in this report which were obtained almost exclusively from State Forests are more generally applicable to the regional koala population.

Any experimental manipulations of existing koala habitat will initially be conducted in other regions having denser populations.

ACKNOWLEDGEMENTS

Many State Forests staff contributed to the fieldwork including Ruth Allen, Arthur Cotterill, Allan Douch, Jack Gray, Gary Jones, Warrick Moore, Warren Purdom, Doug Rowell, Roy Shiels and Margaret Smith. District Foresters Michael Bullen, Steve Dodds and David Ridley initiated and/or supported most of the survey and research work summarised in this paper. Bob Harris and Simon Whittock located koalas for radio-tracking. Drs Wendy Mashado and Alison Spurgeon provided veterinary assistance and Dr John Emmins performed biochemical analyses and provided comparative data. Simon van Holst drew Figures 1 to 3, Karen Hudson assisted with data analysis, Julie Duke and Wendy Whatman typed the manuscript and Joy Gardner edited the document for publication. We also thank the following people for their helpful criticism of earlier drafts of this report: Chris Allen, Wayne Braithwaite, Rod Kavanagh, Alistair Melzer, Vince Phillips, Jim Shields and an anonymous reviewer from The National Parks and Wildlife Service.

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APPENDIX 1

SUGGESTED RESOLUTIONS FROM CORK ET AL. *(1995)*

The first priority for resources should go to comprehensive study of the autecology of koalas in the moratorium area, concentrating on populations rather than individual koalas and focusing on socioecology and other components of population dynamics with a view to identifying what characteristics of favoured environments are important to koalas. This work should aim to, within the two years of the moratorium, erect testable hypotheses about how logging might affect koalas and their habitat.

Efforts should continue to locate further substantial populations of koalas within the region to allow replication of autecological work and later experimentation by habitat manipulation.

Complementary work should be encouraged on at least three other populations in the region if such populations can be located.

There should be a critical assessment of the feasibility, cost-effectiveness, reliability and ecological impact of using trained sniffer dogs to locate koalas, as this is the most promising tool for future surveys of koalas.

There should be a critical assessment of the reliability of using scats to indicate presence or absence of, or habitat use by, koalas and to obtain indices of koala abundance, as this remains one of the most useful surveying tools available.

A regional survey to establish the distribution and abundance of koalas in relation to climate, landform, lithology and soil type, forest type and, if possible, disturbance history in the region should remain a high priority. But it should only proceed when survey designs and methodologies can be formulated that take the problems of rarity and uncertainty of absence records into account so that there is a reasonable likelihood of obtaining a robust predictive model of habitat requirements.

Large scale experimentation to investigate the effects of logging and mitigation regimes on koalas and their habitat should only proceed when clear hypotheses can be formulated about the effects of the treatments and when methods of monitoring are devised that allow statistically unequivocal conclusions to be drawn. An aim of the autecological research should be to move towards making some such experiments possible within two years.

In the interim, hypothesis generation should be facilitated by collecting as much data as possible on previous applications of logging and mitigation regimes to koala habitat in the region.

Design of surveys and experimentation should take into account all land tenures and an aim of any survey should be to establish the relationship between the distribution of koalas and land under any tenure vulnerable to severe disturbance.

It is desirable to involve community groups along with the agencies, universities and other research organisations in the formulation of research priorities, implementation of regional surveys and erection of hypotheses for experimental testing.

National Parks and Wildlife Service and State Forests of New South Wales should discuss methods of obtaining useful data on impacts of logging and mitigation regimes in the course of logging operations outside the moratorium area during the course of the moratorium.

If and when reliable methods for detecting koalas and monitoring their responses to logging are developed, consideration should be given to experimental manipulations to investigate other factors influencing the dynamics of koala populations, including food, predation and fire.

Finally, facilitation of the above actions will require, firstly, the furthering of the Koala Management Plan currently being prepared by State Forests of New South Wales and National Parks and Wildlife Service and, secondly, the establishment of an independent scientific committee to direct and oversight koala research.

APPENDIX 2

KSC PRELOGGING SURVEY METHOD

1. Coupes are to be assessed by the District Forester to consider instituting surveys for koalas taking into account previous knowledge, historical questionnaire information, forest type information and State Forest's Research advice.

2. A suite of surveys is to occur with the following sequence and specifications -

   (a) an intensive transect survey with quadrats - survey 1;
   (b) spotlighting and tape playback surveys - survey 2;
   (c) surveys by State Forests of New South Wales supervisor prior to harvesting - survey 3;
   (d) a subsequent search by the tree faller who has been trained in identification - survey 4.

3. Where evidence of a koala has been determined by the presence of a koala or the combination of scratch and scat evidence, then the "Protocol for Koala Sightings", as determined by the Koala Steering Committee, is enacted.

SURVEY 1: Transect Survey with Quadrats

An intensive survey within the proposed logging coupe will occur prior to logging to determine whether koalas regularly use the coupe.

The survey will involve traverses in areas to be logged. Non-logged areas (such as wildlife corridors) will not be surveyed.

The traverses are to relatively uniformly cover the harvesting area with transects between 50 to 100 metres apart subject to local conditions.

At approximately 25 to 50 metre intervals (depending on the distance between transects) quadrat searches are to be made.

> Quadrat size: 50 cm x 50 cm quadrats are to be placed.
>
> At each search site, four quadrats are to be randomly placed within 10 metres of the transect beneath tree crowns.
>
> The quadrats are to be searched for scat evidence.
>
> Trees at the quadrats and between quadrats are to be examined for koala scratches, koala scats, koalas or predator scats.

While surveying the transect line, all trees between quadrat sites are to be similarly searched (without using quadrats) for scratches, scats, koalas and predator scats.

Possible scratch marks are to be confirmed by quadrat searches for scats.

SURVEY 2: Spotlighting and Tape Playback Surveys

Night time spotlight transects are to complement the day time transects. Surveys are to begin when it is completely dark and end before sunrise using 100 w spotlights powered by 12v batteries.

Vehicle based spotlight transects are to be conducted along main roads, access tracks and fire trails adjacent to the proposed logging coupes using the standardised State Forests of New South Wales Environmental Impact Statement survey procedures. The study area is to be spotlighted from a vehicle travelling 5 kph using two observers and 100 w spotlights. One of the observers should have expertise in identification of animals.

Spotlight transects on foot are also to occur through each coupe proposed for harvesting as marked by reflective tape.

Areas identified by the intensive transect survey as requiring further survey or transects through the centre of each coupe should be spotlight surveyed.

Taped koala calls using a powerful cassette player/speaker system should be played during day surveys as well as spotlight surveys.

Taped calls should be played for two periods of three minutes with a five minute waiting period for responses to the taped calls.

In order to ensure comprehensive surveys, the taped koala calls should occur during any season but in particular during spring and early summer.

Within coupes, taped koala calls are to be played at sites within the coupe which allow extensive audio coverage such as ridges.

Taped playbacks during vehicle based spotlight surveys are to occur about every two kilometres on prominent topographic features.

SURVEY 3: Surveys by State Forests of New South Wales Supervisor Prior to Harvesting

For those coupes surveyed by transect surveys, then:

Prior to harvesting and during the planning of the proposed harvesting activity, the State Forests of New South Wales supervisor shall examine trees for koala scratches, koala scats or koalas and listen for koala calls. Such a survey is to occur while:

- surveying access road locations;
- determining dump locations;
- locating coupe boundaries;
- determining filterstrip location and width;
- undertaking flora and forest type surveys;
- carrying out archaeological site surveys.

State Forests of New South Wales field supervisor and supervising Forester are to carry out searches for koala scratches and scats and koalas during a preview of the plan with the timber mill and contractor representative.

While marking individual trees to be excluded from logging, the State Forests of New South Wales supervising foreman is to carry out searches for koalas in the crown, koala scratches and koala scats.

SURVEY 4: Tree Search Prior to Felling

Contractor crews who are allocated harvesting coupes surveyed for koalas using transects and spotlight/tape playback surveys, are to be trained in:

- identifying koala calls;
- identifying koala scats and scratches;
- the protocol to be followed if a koala is located.

Tree fallers of such crews are to be accredited following training in koala scratch marks, koala calls and scat identification and are to conduct tree searches prior to felling. Accreditation is to occur on a yearly basis with refresher training prior to accreditation.

Contractor crews and tree fallers under the protocol are to stop harvesting immediately evidence of a koala is located and report the occurrence to a State Forests of New South Wales supervisor.

The "Protocol for Koala Sightings", as determined by the KSC, is then enacted.

State Forests of New South Wales supervisors are to discuss the results of the fallers observations on a daily basis wherever possible.

APPENDIX 3

ASTERISK SURVEY METHOD

Background

This is the method applied when a koala or evidence of a koala is detected. The method allows an assessment to be made of the level of use of a particular area and in some cases will enable the delineation of an area of regular use. The technique also provides some data on the composition and structure of the tree stand and the relative use by koala of different species or types of trees

Methods

The tree where a koala was detected is designated as Centre Tree 1. Transects are run on the four cardinal compass points from the centre tree. The transects are 100 m long. All trees within 15 m of the transect line are inspected for signs of koala use, i.e. scratches, scats, koalas.

Trees having scratches but, on first inspection, no scats, are searched using 0.25 m^2 quadrats placed on the ground under the crown. A minimum of four to eight quadrats are searched depending on the size of the crown. Any tree under which scats are found is designated as a centre tree and numbered sequentially if it is more than 20 m from the previous centre tree. Further transects are then established around the new centre tree on those cardinal points which do not coincide with a transect from a previous centre tree. The process continues until no further centre trees are identified.

Additional transects are then established from each of the peripheral centre trees on any of the four intermediate compass points (NE, SE, SW, NW) which do not overlap previous transects.

Thus an area is delineated which contains evidence of use by koala.

Plots are then established around each centre tree consisting of the centre tree and its nine nearest neighbours in each of two size categories (above and below 30 cm dbh). These is a search limit of 25 m radius for each size category and if no trees occur within this limit, only one tree in the category is recorded.

In the plots species, dbhob or diameter class and Keady Crown Class are recorded for each tree greater than or equal to 10 cm dbh. Where diameters are estimated, they are allocated to the following classes - 10-29 cm, 30-59 cm, 60-89 cm, 90-109 cm, >=110 cm. The height of the centre tree and the tallest tree in each of the two categories is also recorded. Where the tallest tree on the site is judged not to represent the site potential, site height is estimated.

The distance to the furthest tree in each of the two categories is recorded as is the distance to the next tree further out in each category.

Aspect slope and topographic position are recorded and the floristic, structural and historical attributes of the site are described.

Scats of koala or other species are noted and koala scats are examined for freshness and uniformity of appearance.

A sample data sheet is attached.

ASTERISK SURVEY DATA SHEET

KOALA NAME TREE NO. OBSERVERS DATE

FOREST DESCRIPTION: (Tree species, ages, logging, fire; understorey species, height, density; groundcover, type, density.) ____

TREE NO.	SPECIES	DIAM.	KEADY	HEIGHT TALLEST	COMMENTS
CENTRE TREE					
1.					
10 TO 30 CM					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
TREE 10 DISTANCE			NEXT FURTHEST		
OVER 30 CM					
(S30-49, I50-69, M70-89, L90-109, VL110+)					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
ESTIMATED SITE HEIGHT					
TREE 19 DISTANCE			NEXT FURTHEST		

ANY OTHER EVIDENCE OF KOALAS?

LOCATION (distance and bearing to reference point/tree number)

OTHER COMMENTS:

APPENDIX 4

OBSERVATIONS OF THE FATE OF KOALA SCATS ON THE FOREST FLOOR

Site	Moisture status	Date established	Date finished	Age mths	Fate	Colour	Odour	Count
1[1]	Dry	12/2/92	22/2/94	24	Slow steady decline in numbers. Gradual weathering	Consistently dark brown.	No odour	First count: 27[3] (12/8/92) Last count: 16
2[1]	Dry	17/2/92	22/2/94	24	Slow steady decline in numbers. Gradual weathering	Consistently dark brown.	No odour	First count: 13[3] 23/3/92 Last count: 1
1b	Dry	16/7/92	23/10/92	3	Rapid decline and weathering green-brown to one month, green again when wet for two+ months.	Green to one week	Eucalypt odour persisted for one month	First count: 10 Last Count: 0
2b	Dry	16/7/92	29/6/93	11	Rapid decline in numbers. Gradual weathering.	Green to one week green-brown to three months, green again when wet for two to three months.	Eucalypt odour persisted for one month	First count: 10 Last count: 0
3[2]	Wet	30/11/92	19/11/93	12	Steady decline and weathering.	Green when wet for one month.	Eucalypt odour persisted for one month	First count: 30 adult/10 juvenile Last count: 0 adult/ 0 juvenile
4[2]	Wet	4/2/93	6/8/93	6	Rapid decline and weathering.	Green when wet for one month.	Eucalypt odour persisted for one month	First count: 19 Last count: 0

1 Detailed observations began after five months
2 Consistently wet
3 Initial number unknown, count from date in brackets

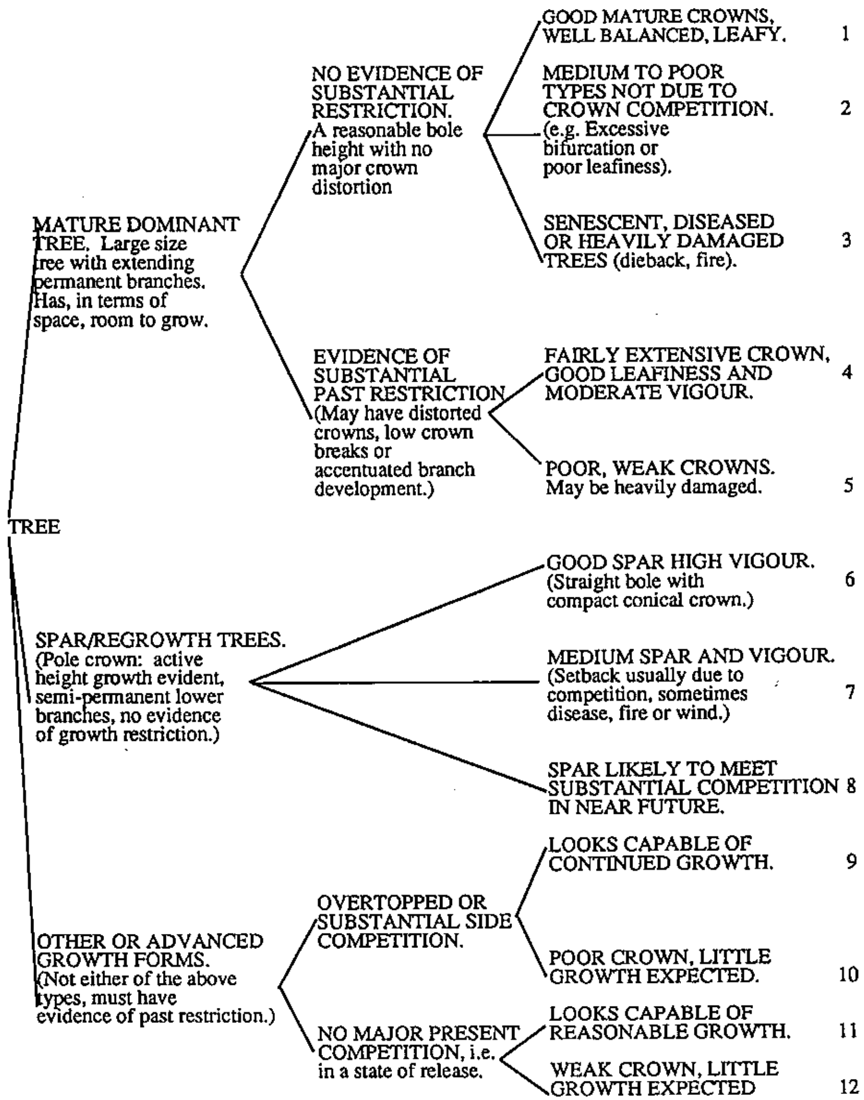
APPENDIX 5

TREE SPECIES USED BY KOALAS AT EDEN

Ruth	Simon	Wayne	Bob	Roberta	Robert	Michelle	Allan	Syndey	Brown Mtn	Honeymoon Ridge	
+	+	+	+	+	+	+				+	*E. sieberi*
+	+	+	+	+	+	+	+				*E. cypellocarpa*
+	+	+	+	+		+					*E. muelleriana*
+		+	+		+			+		+	*E. globoidea*
				+	+		+	+		+	*E. longifolia*
	+	+	+		+						*E. obliqua*
	+	+	+	+							*E. elata*
				+	+			+			*E. agglomerata*
	+	+	+								*E. fastigata*
+		+									*E. maidenii*
		+									*E. bosistoana*
			+								*E. smithii*
								+			*E. consideniana*
									+		*E. dalrympleana*
							+				*C. maculata*
										+	*Angophora floribunda*
							+				*Acmena smithii*
							+				*Backhousia myrtifolia*
							+				*Pittosporum undulatum*
				+							*Allocasuarina littoralis*
						+					*Acacia cognata*
						+					*Elaeocarpus reticulatus*

APPENDIX 6

SUMMARY OF THE MAIN CATEGORIES OF KEADY'S CROWN QUALITY CLASSIFICATION (FLORENCE 1996)



APPENDIX 7

AVERAGE COMPOSITION OF TREE STANDS AT KOALA RADIO LOCATIONS (TREES HA^{-1})

(i) Ruth

Species	dbh class cm <30	30-49	50-69	70-89	90-109	110+	Total
E. bosistoana	1.6	0.1					1.7
E. cypellocarpa	99.8	7.3	4.3	4.4	1.8	0.3	117.9
E. elata	1.6	0.1		0.1	0.1		1.9
E. fastigata		0.6					0.6
E. globoidea	54.3	14.8	1.8	0.3			71.2
E. maidenii	1.1		0.1	0.0	0.3		1.5
E. muelleriana	15.3	3.9	1.9	0.3	0.3	0.1	21.8
E. obliqua	0.5	1.5	1.7	0.7			4.4
E. sieberi	197.8	30.6	3.0	0.7	0.6		232.7
Total	372.0	58.9	12.8	6.5	3.1	0.4	453.7

(ii) Simon

Species	dbh class cm <30	30-49	50-69	70-89	90-109	110+	Total
E. bosistoana	0.2						0.2
E. cypellocarpa	34.9	3.6	3.6	0.9	2.6	0.4	46.0
E. elata	50.8	4.7	2.6				58.1
E. fastigata	64.2	13.0	6.6	4.0	1.6	0.3	89.7
E. globoidea	1.9	0.7	1.5	0.5	0.6		5.2
E. muelleriana	9.8	3.7	2.3	1.3		0.2	17.3
E. obliqua	8.9	1.8	0.6	0.1	1.3	0.2	12.9
E. sieberi	144.4	12.2	6.5	2.2	1.8	0.3	167.4
Total	315.1	39.7	23.7	9.0	7.9	1.4	396.8

(iii) Wayne

Species	dbh class cm <30	30-49	50-69	70-89	90-109	110+	Total
E. bosistoana	1.2						1.2
E. cypellocarpa	83.9	8.3	2.3	0.7	0.6		95.8
E. elata	5.8	1.2					7.0
E. fastigata	0.6	1.8	0.2	0.5			3.1
E. globoidea	48.9	18.4	5.4	1.2			73.9
E. muelleriana	0.9	0.6	1.2				2.7
E. obliqua	39.3	3.2	2.6	3.0	2.4		50.5
E. sieberi	96.1	7.2	0.6		1.1		105.0
Total	276.7	40.7	12.3	5.4	4.1		339.2

(iv) Bob

Species	dbh class cm <30	30-49	50-69	70-89	90-109	110+	Total
E. cypellocarpa	17.4	4.0	2.8	2.3	0.5	1.3	28.3
E. elata	46.0	7.5	3.9	0.3			57.7
E. fastigata	14.9	3.6	0.7	1.0	0.1	0.0	20.3
E. globoidea	23.0	3.6	3.7	2.1	0.2		32.6
E. muelleriana	8.0	4.3	3.6	2.6	0.9	0.2	19.6
E. obliqua	18.1	0.9	0.9	0.9	0.4		21.2
E. sieberi	40.2	10.2	6.2	4.4	1.2	0.1	62.3
E. smithii		0.0		0.1	0.0		0.1
Total	167.6	34.1	21.8	13.7	3.3	1.6	242.1

(v) Roberta

Species	dbh class cm <30	30-49	50-69	70-89	90-109	110+	Total
E. agglomerata	7.1	0.4	0.5	0.1			8.1
E. bosistoana	0.1						0.1
E. cypellocarpa	7.8	4.0	1.7	2.2	0.2	0.1	16.0
E. elata	0.3	0.1	0.1				0.5
E. globoidea	0.2		0.9				1.1
E. longifolia	3.6	1.7	1.6	0.4	0.1		7.4
E. muelleriana	15.3	6.3	9.1	2.0	0.9		33.6
E. obliqua		0.1		0.2			0.3
E. sieberi	69.7	4.6	3.9	1.8	0.5	0.1	80.6
E. tricarpa	0.5	0.2	0.3				1.0
Total	104.6	17.4	18.1	6.7	1.7	0.2	148.7

(vi) Robert

Species	dbh class cm <30	30-49	50-69	70-89	90-109	110+	Total
E. agglomerata	1.0	1.6	1.6				4.2
E. cypellocarpa	9.8	2.2	1.0	1.0	0.5		14.5
E. globoidea	6.9	5.8	3.7	4.1			20.5
E. longifolia	1.2	1.5	2.1	0.6			5.4
E. muelleriana	1.9	8.5	4.8	3.1	0.4		18.7
E. obliqua	0.5		0.3	1.0	0.5		2.3
E. sieberi	47.6	4.9	5.9	2.2			60.6
E. tricarpa	0.3	0.5	1.0				1.8
Total	69.2	25.0	20.4	12.0	1.4	0	128.0

(vii) Michelle

Species	dbh class cm <30	30-49	50-69	70-89	90-109	110+	Total
E. cypellocarpa	63.3	4.5	2.2				70
E. longifolia	13.1	0.2					13.3
E. muelleriana	30.9	6.5	3.8	1.2			42.4
E. sieberi	93.9	4.0	0.6				98.5
Total	201.2	15.2	6.6	1.2			224.2

(viii) Allan

Species	dbh class cm <30	30-49	50-69	70-89	90-109	110+	Total
A. smithii	0.5						0.5
B. myrtifolia	64.4	1.1		0.3			65.8
E. bosistoana	0.7						0.7
E. botryoides	5.0	0.8	0.8	0.6			7.2
E. longifolia	0.3		0.2			0.8	1.3
E. cypellocarpa		1.2	1.1	1.0	1.1		4.4
E. globoidea	1.1						1.1
C. gummifera		0.3					0.3
C. maculata	60.4	13.6	13.1	2.4	0.3		89.8
E. muelleriana	32.5	10.7	3.0	1.1			47.3
E. tricarpa	1.4		0.5	0.2			2.1
Total	165.8	28.2	18.7	5.6	1.4	0.8	220.5

APPENDIX 8

FOREST TYPES (FORESTRY COMMISSION OF NEW SOUTH WALES 1989) IN WHICH KOALAS HAVE BEEN OBSERVED AT EDEN

23. Myrtle

This type includes a number of communities which are dominated by various myrtles (species of family Myrtaceae), excluding the Water Gum-Coachwood and Lilly Pilly types (types 13 and 14). The communities typically occur as relatively narrow bands fringing coastal creeks and occupying gully sites, and sometimes extending up the adjacent slopes for some distance. All forms of the type are marked by low height development (usually under 9-12 m) and simple structure. Commonly recognised variants (which can, if necessary, be separated as sub-types) include the stands dominated by Grey Myrtle, widespread on the South Coast (Bodalla, Wandella State Forests), where it can cause silvicultural problems, but found also in other coastal areas (*eg* Glenugie State Forest); by *Waterhousea floribunda*, usually found in dry forest areas (eg. Stroud district); by *Choricarpia leptopetala*, which also can be a silvicultural problem (*eg* Watagan group of forests); and by *Tristania neriifolia* in parts of the Central Coast.

50. Bangalay

Composition: In this type Bangalay occurs as a tall tree making up over 50 per cent of the stand, with Sydney Blue Gum, Turpentine, Red Bloodwood, Mountain Grey Gum and other species as associates and with usually a fairly dense understorey of Wattles, Lilly Pilly and other species.

Nature: Wet sclerophyll forest up to 40 m high. This type replaces Sydney Blue Gum type in moist, sheltered gullies on the South Coast, where the two species tend to merge together, the Bangalay type being the more common south of Batemans Bay.

Occurrence: Found on the south coast between Wallaga Lake and the Shoalhaven River catchment. Typical examples occur in Mogo State Forest and Yerriyong State Forest. An unusual occurrence is along the Nepean River upstream from Camden.

Note: Bangalay may also dominate certain other communities in situations near the coastline, where it occurs as a small to medium sized, frequently rather gnarled tree. These communities are described under the Bangalay-Banksia type (No. 108).

63. Woollybutt

In this type Woollybutt occurs either as a clear sole dominant or as a co-dominant with Ironbark, Stringybark or both. The Ironbark present is usually Grey, but may be Red on the far South Coast; the Stringybark is usually White or Blueleaved. The type occupies a rather similar position to the previous one in parts of the South Coast, occurring on ridges in areas that often carry moister and higher quality forest types in adjacent sites. Forms a dry sclerophyll forest up to 30 m high. Other common associates include Red Bloodwood, Roughbarked and Smoothbarked Apples and Silvertop Ash. The type is relatively widespread in both coastal and foothill forest areas on the South Coast south from Nowra; typical sites occur on Bodalla State Forest and Murrah State Forest.

70. Spotted Gum

Composition: This is a variable type in which Spotted Gum dominates the stand and may occur in pure stands or with a wide range of other eucalypts as associates. These associates may include Yellow Stringybark and various other Stringybarks, Woollybutt, Silvertop Ash, Red Bloodwood, Mountain Grey Gum, White Mahogany, Ironbarks, Tallowwood, Sydney Blue Gum, Brush Box, Turpentine, Forest Red Gum and others. The understorey is variable; in parts of the South and Central Coast there is commonly a dense understorey of Burrawang, while elsewhere the understorey may contain grasses or xerophytic (rarely mesophytic) shrubs. Where necessary, various specific sub-types can be recognised.

Nature: The type ranges from dry sclerophyll forest to wet sclerophyll forest, and the height can range from about 20 m to 45 m. It occurs on a variety of soils, which are however usually rather heavy in texture, under a rainfall of about 750 to 1250 mm.

Occurrence: Widespread throughout the coastal districts, usually at elevations of below 300 m. Typical localities include Bodalla State Forest, Bendandarah State Forest, Shoalhaven State Forest, Newport Plateau, Wyong Management Area, Wallaroo Management Area, Yarrat State Forest, Tabbimoble State Forest. An unusually western occurrence, where Spotted Gum is associated with Red and Blueleaved Stringybarks, Red and Blueleaved Ironbarks and Black Cypress Pine, is present in Curryall State Forest.

75. Spotted Gum-Yellow/White Stringybark

Composition: Spotted Gum is associated normally with Yellow Stringybark, less commonly with White Stringybark. Certain other species, including Mountain Grey Gum, Woollybutt and various other Stringybarks, may be associated, and there is usually a fairly dense understorey.

Nature: A wet sclerophyll forest of high site quality, found occurring on southeasterly aspects towards the inland limit of Spotted Gum on the central and lower South Coast. It serves to link the Spotted Gum league with the Messmate-Brown Barrel league. Stands with White Stringybark as co-dominant tend to have a drier appearance than those with Yellow Stringybark.

Occurrence: Found south of Batemans Bay in favoured sites, *eg* in the western parts of Bodalla State Forest. Stands with White Stringybark occur particularly in some coastal forests of the Batemans Bay district.

102. Yertchuk

Found on the South Coast and the southern parts of the Central Coast, extending into the escarpment zones and occurring on dry, shallow soils of low fertility, particularly on ridgetops and exposed slopes. The type is of low height (rarely over 20 m) and may contain a wide range of associates, with Smoothbarked Apple often occurring as a co-dominant. Other associates may include Roughbarked Apple, various Stringybarks, Narrowleaved Peppermint, Scribbly Gum and Red Bloodwood. Typical examples occur on Bodalla State Forest and Dampier State Forest.

112. Silvertop Ash

Composition: Silvertop Ash dominates these stands, constituting from 50 per cent to commonly 100 per cent of the stems. Associated species are varied and include Messmate, Mountain Grey Gum, White Ash, Mountain Gum, Blackbutt, Yellow Stringybark, Peppermints, Woollybutt, Ironbarks, Red Bloodwood and Roughbarked and Smoothbarked Apples.

Nature: Whilst typically forming a dry sclerophyll forest, usually under 30 m in height, this type in certain areas approaches wet sclerophyll forest in structure and 40 m in height; in such cases it can provide a valuable commercial type. It characteristically occupies ridgetop positions.

Occurrence: Found widely through the Southern and Central Tablelands and Coast districts, and reaching its best development on the far South Coast. Typical examples occur in the Eden district, Dampier State Forest, Tallaganda State Forest and on the Blue Mountains.

114. Silvertop Ash-Stringybark

Composition: Silvertop Ash and one or more species of Stringybark (including Yellow, White, Brown, Blueleaved and Thinleaved) dominate the stand, occurring with such associates as Messmate, Brown Barrel, Mountain Grey Gum, Peppermints, Red Bloodwood, Apples, Grey Gum, Scribbly Gum and Snow Gum.

Nature: Like the Silvertop Ash type, this is a widespread type in the Central and South Coast and Tablelands, usually occurring as dry sclerophyll forest but occasionally forming a wet sclerophyll forest up to 40 m in height in the South Coast and escarpment areas.

Occurrence: The type occurs generally in the same localities as the Silvertop Ash type.

121. Blueleaved Stringybark

This type is recognised from the more generalised Coastal Stringybark type (No. 123) because of its distinctive appearance and its regular occurrence on poor, dry ridges where, nonetheless, it may attain a height of 30 m, though usually much lower. It is common on the South Coast and extends up into the Central Tablelands and, spasmodically, to the North Coast (eg. Mt Boss State Forest) and to the Mudgee district. Associates may include other Stringybarks, Roughbarked Apple, Peppermint, Red Bloodwood and Grey Gum.

123. Coastal Stringybark

This is a similar type to the previous one, but it occurs in the Southern and Central Tablelands and through the coastal districts, certainly to as far north as the Gloucester district. It is comprised of one or more of such Stringybarks as White, Thinleaved and Brown. Other species may be associated with these, including Peppermints, Apples, Red Bloodwood, Ironbarks, Silvertop Ash, Woollybutt and Grey Gum. It is particularly widespread in the South Coast districts (mainly towards the escarpment), where it occurs on ridges and the drier slopes.

132. Stringybark-Gum

White Stringybark and/or Thinleaved Stringybark occurs as a co-dominant with either Maiden's Gum or Mountain Grey Gum. The distribution of the Gum within this association appears to be largely influenced by soil moisture availability: Maiden's Gum occurs most frequently on ridge tops and the drier aspects whilst Mountain Grey Gum has a preference for the more sheltered sites. Stand height tends to vary from 15 m to 30 m. Again this variation appears to be related to moisture availability. Associated species include Blueleaved Stringybark, Red Box and Appletopped Box. The understorey species are typically xerophytic in nature. Low shrubs and grasses dominate the ground stratum with percentage ground cover decreasing noticeably on the drier sites. This type appears to constitute a broad transition between the Coastal Stringybarks in the foothills and the Southern Blue Gum types in the escarpment and Tablelands. Typical examples of this type occur in Nalbaugh State Forest (particularly along the eastern fall into the Wog Wog River), Coolangubra State Forest and the north-eastern section of Bondi State Forest.

140. Snow Gum-Mountain/Manna Gum

Composition: Snow Gum is associated with one or more of three closely related Gums: Mountain Gum, Manna Gum or Candlebark. These form the stand dominants, whilst other associated species can come from a wide range of highland species, including Peppermints, Brown Barrel, Alpine Ash and Black Sallee.

Nature: This type varies from savanna woodland to wet sclerophyll forest, and from about 10 m to 30 m in height. It most commonly occurs as a forest formation and is probably the most widespread type in this league, occupying extensive areas throughout the Tableland districts in cold sites with a rainfall in excess of about 750 mm a year. It is most common on soils of heavy texture. Where necessary sub-types can be recognised on the basis of the actual species which is co-dominant with Snow Gum.

Occurrence: Widespread in the moister and colder parts of the Tablelands, at elevations of from about 600 m to 1500 m. Typical occurrences include the Ebor-Guyra district, Barrington Tops district, Warung State Forest, Mt Canobolas and Bago State Forests.

150. Messmate

Composition: Stands clearly dominated by Messmate. Narrowleaved Peppermint is the most common associate, and may on occasions approach co-dominance with Messmate. Other associates may include Manna Gum, Mountain Grey Gum, Brown Barrel, Silvertop Ash and Mountain Gum.

Nature: This type most commonly occurs as dry sclerophyll forest, but occasionally tends towards wet sclerophyll forest. Stand height is in the range of 20 m to 35 m. The type tends to occupy poorer sites than the following two types.

Occurrence: Central and Southern Tablelands. Specific localities include Banshea State Forest and eastern side of Tallaganda State Forest.

152. Messmate-Gum

Composition: Messmate occurs with either Manna Gum or Mountain Grey Gum (rarely other related Gums) as the dominant species; in the Northern Tablelands these species are sometimes replaced by Roundleaved Gum as the co-dominant species with Messmate. Associates may include Silvertop Stringybark, Yellow Stringybark, certain other Stringybarks (eg. White and Diehard), Silvertop Ash, New England Blackbutt and very characteristically certain Peppermints (especially Narrowleaved).

Nature: This type can occur as both dry and wet sclerophyll forest, with a height range of about 25 m to 35 m. It occupies generally drier sites than the previous type, particularly where soil is shallower, in the same general area.

Occurrence: Found in all Tableland districts. Examples include Bondi State Forest, Monga State Forest, Carrai State Forest and Styx River State Forest.

154. Brown Barrel

Composition: Brown Barrel is the clear dominant and may occur in pure stands, usually of very high quality. Where subordinate associates are present, these may include Messmate, Shining Gum, Mountain Grey Gum, Manna Gum, Sydney Blue Gum, Tallowwood and Peppermints. On parts of the Southern Tablelands (eg. Badja State Forest), Narrowleaved Peppermint occurs as a co-dominant with Brown Barrel in stands that are of lower site quality than is normal for this type. Where they occur, such stands should be recognised as a distinct sub-type.

Nature: This type occupies the most favoured sites, occurring in sheltered situations on deep, moist, fertile soils where it forms a wet sclerophyll forest up to 60 m in height. There is usually a fairly dense understorey, commonly consisting of rainforest species. At least in the northern areas, this type tends to be replaced by rainforest in the absence of repeated fire.

Occurrence: Found chiefly in the eastern parts of the Tablelands regions, in the same general location as the previous types in this league but usually occupying the most favoured sites. Examples occur on Bondi State Forest, Badja State Forest, Monga State Forest, Oberon area, Barrington Tops area, Styx River State Forest.

155. Brown Barrel-Gum

Composition: In this type Brown Barrel is co-dominant with one or more species of Gum, including Mountain Grey Gum, Shining Gum, Maiden's Gum, Manna Gum and Mountain Gum. Other associated species include Messmate, Yellow Stringybark, Silvertop Ash, various Peppermints and other Stringybarks, and Sydney Blue Gum. Rainforest species including Coachwood, Sassafras and Negrohead Beech may occur in the understorey.

Nature: Similar to the previous type, though commonly tending to occur on the slightly driver and less favoured sites. Forms a wet sclerophyll forest up to 50 m in height.

Occurrence: Generally as for the previous type, but occurring further westward as far as the Brindabella Range in the ACT. Localities include Coolangubra State Forest, Bondi State Forest, Monga State Forest, Tallaganda State Forest, Oberon area and Ebor area.

156. Brown Barrel/Messmate Ash

Composition: Silvertop Ash, or more rarely White Ash, occur with Brown Barrel, Messmate or, commonly, both species as the dominants in a stand, with other associates including various Stringybarks and Peppermints, Manna Gum and Mountain Grey Gum.

Nature: This type varies from dry to wet sclerophyll forest, with a height range of from about 18 m to 35 m, rarely higher. It occurs on ridgetop situations, in areas where more favoured sites support one or more of the other Brown Barrel and Messmate types.

Occurrence: Confined to the eastern parts of the Southern Tablelands, where it is fairly common in such areas as Bondi State Forest and Monga State Forest; stands with White Ash as the co-dominant are recorded from Badja State Forest and Tallaganda State Forest.

157. Yellow Stringybark-Gum

Composition: This type has Yellow Stringybark and usually Mountain Grey Gum as the dominants, though Maiden's Gum and less commonly Manna Gum may replace Mountain Grey Gum or be associated with it. Other associated species can include Silvertop Ash, Messmate, Brown Barrel, Coastal Grey Box, other Stringybarks, various Peppermints (including Gully and River), Bangalay, Blackbutt, Spotted Gum and Woollybutt.

Nature: Normally a wet sclerophyll forest ranging from about 25 m to 45 m in height, and occurring in favoured sites at generally lower altitudes than the previous types in this league.

Occurrence: This type is well developed on the central and lower South Coast and extends thence up on to the escarpment of the Southern Tablelands and parts of the Central Tablelands. Localities include Bodalla State Forest and Currowan State Forest.

Note: This type tends to link the Southern Blue Gum type (No. 158), where the Gum is clearly dominant, with the Yellow Stringybark type (No. 169). Like the Southern Blue Gum type, it can provide valuable habitat for arboreal wildlife.

158. Southern Blue Gum

Composition: This type is dominated by one (rarely by two) of the Southern Blue Gum group-Mountain Grey Gum, Maiden's Gum and Shining Gum (but not Eurabbie, see type No. 164). Associated species include Messmate, Brown Barrel, Silvertop Ash, Peppermints, Snow Gum and Manna Gum. The type should be known by the name of the dominant species present locally (*eg* Mountain Grey Gum type; Maiden's Gum type); if two or more species occur in a district, appropriate sub-types should be recognised.

Nature: These stands normally occur as wet sclerophyll forest up to 50 m in height. Though variable in occurrence, they commonly occupy deep, fertile soils in favoured aspects. Sometimes the stands are of lower site quality and appear as dry sclerophyll forest: these stands can occur in intimate mosaics with stringybark and silvertop ash-dominated stands (eg. Type Nos. 112 and 123), and merge into the Gum-Box-Stringybark type (No. 88).

Occurrence: These stands are found mostly along the escarpment of the Southern and Central Tablelands, with occasional scattered occurrences on the New England Tablelands (eg. Styx River State Forest, Wollombombi Falls). In the south they extend also into the coastal areas. Localities include Glenbog State Forest, Mt Dromedary, Monga State Forest and Victoria Pass (Blue Mountains).

162. White Ash

This type occurs commonly in the moist escarpment zone between the South Coast and Southern Tablelands, occurring on steep slopes (usually with southerly or easterly aspect) and fringing elevated peaks. White Ash frequently occurs in almost pure stands, though it may be associated with such species as Silvertop Ash, Mountain Grey Gum, Narrowleaved Peppermint, Messmate and Brown Barrel. Stand height may reach to 35 m, though because of the exposed sites it is commonly much less. Localities include Mt Dromedary FR, Currowan State Forest, Kangaroo Valley and Tallaganda State Forest. In some localities White Ash may be replaced by one of its rarer relatives, such as Jilliga Ash (*Eucalyptus stenostoma*) or Pigeon House Ash (*E. triflora*), and in such cases these should be recognised as specific sub-types.

165. Gully Peppermint

This type commonly occurs associated with the Yellow Stringybark (No. 157) and various of the Brown Barrel and Messmate types (Nos. 151-156) in the escarpment zone of the Southern Tablelands, where it frequently forms a wet sclerophyll forest up to 40 m high and may extend from gullies up to the ridges. Localities include Nullica State Forest, Dampier State Forest, Tallaganda State Forest, Robertson district. The type extends north to parts of the Central Tablelands.

166. River Peppermint

This is a characteristic creek-bank community, found on the South Coast and extending into the adjoining areas of the Tablelands. River Peppermint commonly occurs in pure stands, or it may be associated with a number of other species, including River Oak, Roughbarked Apple, Blue Box, Appletopped Box, Mountain Grey Gum, Manna Gum, Bangalay, Messmate, Brown Barrel and Forest Red Gum. It normally appears as wet sclerophyll forest up to 40 m in height, though usually less than 30 m high, occupying alluvial flats, but sometimes extending towards the ridge tops. Localities include Nadgee State Forest, Bodalla State Forest, Currowan State Forest, and north to the Colo River.

169. Yellow Stringybark

Composition: Yellow Stringybark occurs as the clear dominant in this type. Associated species may include Silvertop Ash, Messmate, Brown Barrel, Coastal Grey Box, other Stringybarks and various Gums.

Nature: A type of highly variable site quality. Although normally a wet sclerophyll forest up to 40 m in height and occurring in moist, favoured sites in coastal districts, the type can also be found with lower height and a drier appearance growing on dry ridge tops.

Occurrence: Found particularly on the far South Coast, but extending north to the Nowra district. Localities include Nullica State Forest, Yambulla State Forest, Dampier State Forest, South Brooman State Forest and Yerriyong State Forest.