

Does size matter? Tree use by translocated Koalas

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Abstract

Over-browsing of Manna Gum *Eucalyptus viminalis* and, in some instances, Swamp Gum *E. ovata* has occurred in areas where Koalas *Phascolarctos cinereus* have been translocated. A 26-month study of 30 radio-tracked translocated koalas examined tree use at three release forests in the Ballarat region. Tree species and tree diameter used by the koalas were recorded. Twenty tree species were used by the released koalas. Seven tree species were surveyed in the three forests. Diameter at Breast Height Over Bark (DBHOB) of trees surveyed was significantly different between forests and species and there was a significant interaction between species and forests ($p < 0.001$, $F = 3.48$). Koalas will use a wide variety of tree species if available and show a preference for larger trees. (*The Victorian Naturalist* 122 (1) 2005, 4-13).

Introduction

The Koala *Phascolarctos cinereus* is the largest arboreal marsupial living in Australia. Before the arrival of Europeans, its distribution encompassed the eastern and south-eastern lowland eucalypt forests of Australia, between Queensland and South Australia (Martin and Lee 1984; Phillips 1990). From the end of the 19th century through to the 1920s, following intensive hunting by white Australians, deforestation, wildfires and disease (Warneke 1978; Phillips 1990), many koala populations throughout Australia crashed. Around 1000 koalas survived in Victoria (Lewis 1934). Meanwhile, between 1880 and 1900, a few koalas were introduced from Corinella (mainland Victoria) to French Island in Western Port Bay (approximately 70 km south-east of Melbourne) (Lewis 1934, 1954).

The Koala's diet consists mostly, but not exclusively, of foliage from the genus *Eucalyptus* (Hindell *et al.* 1985). In Victoria, their highly preferred tree food species include Manna Gum *Eucalyptus viminalis* and Swamp Gum *E. ovata* (Hindell *et al.* 1985; Hindell and Lee 1987; Martin and Handasyde 1999) as well as River Red-gum *E. camaldulensis* and Southern Blue-gum *E. globulus* (Department of Sustainability and

Environment (DSE) 2004). The population of koalas on French Island increased rapidly due to their inability to disperse from the island, the abundance of the optimal food tree species (*E. viminalis* and *E. ovata*), the absence of predators (Pratt 1937) as well as their *Chlamydia*-free status (Backhouse and Crouch 1990). By the 1920s, eucalypt defoliation had become a problem, and in 1923, a translocation program was begun to alleviate the pressure on the island's vegetation (Phillips 1990). Koalas were released into their former habitat on the Victorian mainland as well as onto other islands. Up to now, approximately 21 000 koalas have been translocated in Victoria (P. Menkhurst 2004 pers. comm. 30 April). Initial release sites were on other islands because these were considered safe havens (DSE 2004). These sites were mainly characterised by the presence of *E. viminalis* with little variety of other tree food species. This choice was made because it was believed that koalas would eat only a few eucalypt species. Over-browsing of *E. viminalis* and *E. ovata* has been occurring on islands and in isolated forested areas on the mainland (e.g. Framlingham Forest and Mount Eccles National Park). Past studies have indicated that koalas are more generalists than once suspected (Warneke 1978; Martin and Lee 1984; Phillips 1990) and would use a wide variety of tree species when available. Since the 1980s, the policy has been to avoid releases into isolated areas and into forests where *E. viminalis* is the prevalent species (DSE 2004).

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One of the aspects that has been poorly investigated in koala research is the size of the trees used by koalas. Past studies have acknowledged tree size as one of the meaningful aspects to take into account when considering the long-term survival of hollow-dependent arboreal mammals in Australia (Gibbons and Lindenmayer 2002; Wormington *et al.* 2003) and overseas (e.g. Fox Squirrel *Sciurus niger*) (Conner and Godbois 2002). Koalas have also been shown to have a preference for larger trees in a variety of forest types (Hindell *et al.* 1985; Hindell and Lee 1987; Melzer 1995 in Moore and Foley 2000; Phillips and Callaghan 2000; Santamaria 2002). One hypothesis is that a large trunk often supports a large crown (Niklas 1994), consequently more food availability (White 1994) and shelter (Hindell *et al.* 1985). Koalas' preference for larger trees has also been associated with their ability to climb (Hindell and Lee 1990).

A 26-month study was undertaken to investigate the outcome of koala translocation in three forests in the Ballarat area. Creswick, Enfield and Lal Lal Forests were selected because of the variety of tree food species available to koalas for fodder and/or shelter and the limited availability of *E. viminalis*. This paper will focus on one of the aspects of the research: tree species use by the translocated koalas with emphasis on tree size.

Methods

Koalas

Thirty koalas were relocated from French Island to three forests in the Ballarat region (Victoria). Twenty females (ten sub-adults and ten adults) and ten males (five sub-adults and five adults) were caught. Sub-adult koalas in this study were independent animals between one and three years of age, established by tooth wear (Martin 1981). The thirty koalas were released into the three forests on 21 October 1997 and radio-tracked for 26 months until December 1999. Koalas were radio-tracked and located during the day (between 6:00 am and 1:00 pm) They were tracked once a week for the first two months, then every two weeks for the following four months, and once a month for the last 20 months.

Site of origin

French Island is situated about 70 km south-east of Melbourne (in Western Port Bay, Victoria). Its area is approximately 17 410 ha; two thirds of the Island is National Park (proclaimed in 1997). Approximately 20% (about 220 ha) of the koala habitat on the island is scattered throughout the Park, the remainder is in remnant patches scattered across privately owned farmland (Parks Victoria 1998). Four indigenous species of eucalypts remain on the island: *E. viminalis*, *E. ovata*, Messmate Stringybark *E. obliqua* and Narrow-leaved Peppermint *E. radiata*. Koalas on the island show a strong preference for the first two species to the point that these are often defoliated (Martin 1985). Koalas have been consistently translocated from French Island by the Victorian Government since 1923 (DSE 2004) to avoid further defoliation of trees. Koalas studied during this research represented a small percentage of the koalas which were translocated from the island by the then Department of Natural Resources and Environment (now DSE) in 1997.

Release sites

The sites chosen to release the koalas were Creswick State Forest and Park (north-east of Ballarat), which is approximately 6985 ha including a softwood plantation (approximately 2850 ha) abutting the State Forest, Enfield State Forest and Park (south-west of Ballarat), which is about 9054 ha. A softwood plantation (approximately 54 ha) also abutting this State Forest; and Lal Lal State Forest (south-east of Ballarat) approximately 1550 ha.

Sites were chosen because of the scattered presence of *E. viminalis* and the presence of a variety of other eucalypt species (Table 1). The three forests chosen are classified as Open Forest (Land Conservation Council (LCC) 1980).

More detailed descriptions of the vegetation can be found in the Ecological Vegetation Classes (EVC) (Commonwealth and Victorian Regional Forest Agreement Steering Committee (CVRFASC) 1999). The vegetation at these sites has been classified under several EVCs. Vegetation types found at the release sites also occur in large areas throughout western Victoria.

Tree species listed in the descriptions might not be found in some sites within the release forests. Furthermore, species non-characteristic of this region, native and non-native introduced tree species, were recorded during this study.

Survey

The trees in which koalas were found were given a sequential number and tagged for future reference. When the same koala was found on a previously marked tree, the tree was counted only once. If a different koala was located in an already marked tree, the tree was counted again. Species and diameter at breast height over bark (DBHOB) of the trees occupied by koalas were recorded. *Eucalyptus obliqua* and Brown Stringy-bark *E. baxteri* were grouped together due to the difficulty of distinguishing the two species in the absence of accessible buds and fruits, and the similarity of their trunks often slightly burnt by the latest bushfire.

To test whether koalas were actively selecting trees according to species or size, the frequency and size class distribution of each species were estimated in each forest using Point-Quarter Sampling (Brower *et al.* 1998). Fourteen 200 m transects were randomly located through the areas used by the translocated koalas. From each point along the transects, the nearest tree in each quadrant (NW, NE, SE, SW) was selected for identification and measurement of DBHOB. During the survey, *E. obliqua* and *E. baxteri* were grouped together.

Statistical analyses

A two-way ANOVA was used to compare DBHOB of the surveyed trees and the trees used by the koalas amongst the three forests and amongst species (data were transformed to base 10 logarithms). A *G*-test (Fowler *et al.* 1998) was performed to compare the frequencies of the surveyed tree species and the frequencies of the species used by the translocated koalas in Creswick, as well as classes of DBHOB of trees surveyed and the trees used by the koalas in all three forests.

Results

Tree Species

Koalas were found in 20 tree species in all. In Lal Lal, koalas used 15 species in

Creswick 16 and 20 in Enfield. Some of these were planted on private properties and/or plantations (e.g. Monterey Pine *Pinus radiata* and Blue Gum *E. globulus*) where koalas dispersed during the study period. Eight tree species were surveyed in Creswick (Fig. 1), eight in Enfield (Fig. 2) and 11 in Lal Lal (Fig. 3). Analysis between the frequencies of the surveyed tree species and the frequencies of the species used by the translocated koalas in Creswick showed that proportions were significantly different ($p < 0.01$, $df = 5$). The frequency of koalas using *E. viminalis* was higher than the surveyed frequency of this species (Fig. 1). The frequencies of the surveyed *E. ovata* and the frequencies of usage of this species were similar. Stringybark species (*E. macrorhyncha*, *E. baxteri* and *E. obliqua*) were strongly avoided at this site. Statistical tests on the frequencies was not carried out on the Enfield data due to the great difference in the number of tree species surveyed and the species used by the koalas. Nevertheless, Fig. 2 indicates that the percentage of stringybarks (*E. obliqua* and *E. baxteri*) and *E. ovata* used by the koalas is higher than the percentage of the species surveyed in the forest. Although numbers are very low, the data also suggest that the percentage use of *E. viminalis* was higher than the percentage of the species surveyed. Analysis could not be performed on the Lal Lal data because the value of some frequencies was less than 5. Nevertheless, the data suggests that some species surveyed, such as *E. ovata* and *E. radiata*, have been preferred; other species such as Broad-leaved Peppermint *E. dives* have been used at a low frequency (Fig. 3). Use of *E. viminalis* appears to be similar to the frequency of this species in the area. The use of Sugar Gum *E. cladocalyx* was limited to an old (9 years of age) female that spent 45% of her time in a private property, moving amongst planted *E. cladocalyx*.

DBHOB

Analyses and box-plots on the diameter of trees surveyed in the three forests are shown in Table 2 and Fig. 4 respectively. DBHOB of trees surveyed was significantly different amongst forests ($p = 0.047$, $F = 3.73$) and species ($p = 0.019$, $F = 4.28$)

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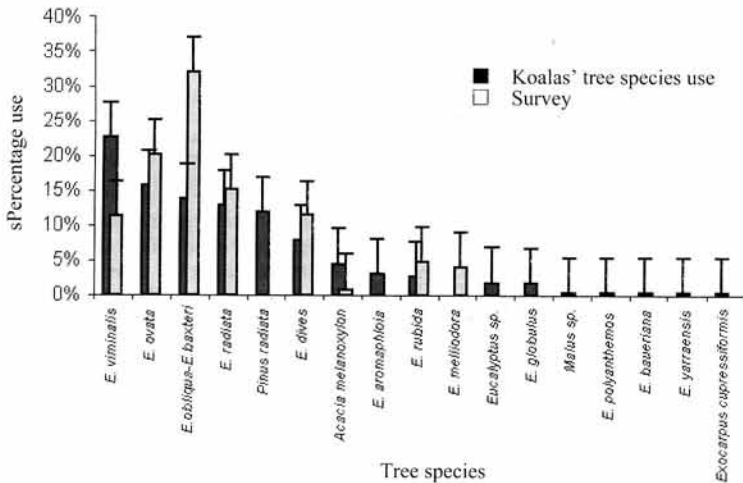
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Table 1. Tree species as listed by the Land Conservation Council (1980) Victoria in the Creswick, Enfield and Lal Lal Forests.

Sites	Common overstorey species	Associated tree species	Common understorey species
Creswick	Messmate Stringybark <i>Eucalyptus obliqua</i> (Open Forest III)	Narrow-leaved Peppermint <i>E. radiata</i> , Candlebark <i>E. rubida</i> , Manna Gum <i>E. viminalis</i> , Broad-leaved Peppermint <i>E. dives</i> , Scent Bark <i>E. aromaphloia</i> , Swamp Gum <i>E. ovata</i> , Monterey Pine <i>Pinus radiata</i> (plantation)	Blackwood <i>Acacia melanoxylon</i> , Silver Common Cassinia <i>Cassinia aculeata</i>
Enfield	<i>E. obliqua</i> , Brown Stringybark <i>E. baxteri</i> , <i>E. ovata</i> , <i>E. rubida</i> , (Open Forest II)	<i>E. aromaphloia</i> , <i>E. radiata</i> , <i>E. dives</i> , Red Stringybark <i>E. macrorhyncha</i> , <i>P. radiata</i> (plantation)	<i>A. melanoxylon</i> , Late Black Wattle <i>A. mearnsii</i> .
Lal Lal	<i>E. obliqua</i> (Open Forest II)	<i>E. radiata</i> , <i>E. rubida</i> , <i>E. dives</i> , <i>E. aromaphloia</i> , <i>E. ovata</i>	<i>A. melanoxylon</i> , <i>A. dealbata</i> , <i>C. aculeata</i> .

**Fig. 1.** Percentage of tree species used by the translocated koalas compared to percentage frequency of tree species in Creswick State Forest and Park. *Eucalyptus obliqua* and *E. baxteri* have been combined. Trees surveyed n=124; trees used by koalas n=247.

(Fig. 5). There was also a significant interaction amongst species and forests ($p < 0.001$, $F = 3.48$) indicating that the size of trees of each species could be influenced by the forest type and/or history.

Analyses and box-plot of the diameter of trees used by the koalas in the three forests is shown in Table 3 and Fig. 6, respectively. There was no significant difference in the size of trees used amongst the three forests, but there was a significant difference of DBHOB amongst the different

species of trees used ($p = 0.001$, $F = 7.34$). This difference can be attributed to two species (Fig. 7), *E. viminalis* and *Acacia melanoxylon*. When these two species are not taken into account, the DBHOB of trees used by the released koalas is not significantly different across the species and the forests. It is also shown that there is no interaction between forests and species, indicating that the size of trees of different species chosen by the koalas does not vary between forests.

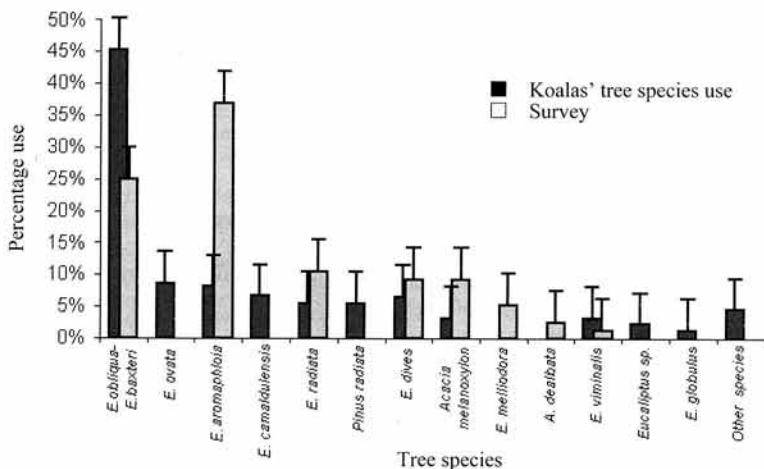


Fig. 2. Percentage of tree species used by the translocated koalas compared to percentage frequency of tree species in Enfield Forest. *Eucalyptus obliqua* and *E. baxteri* have been combined. Trees surveyed $n=128$; trees used by koalas $n=256$.

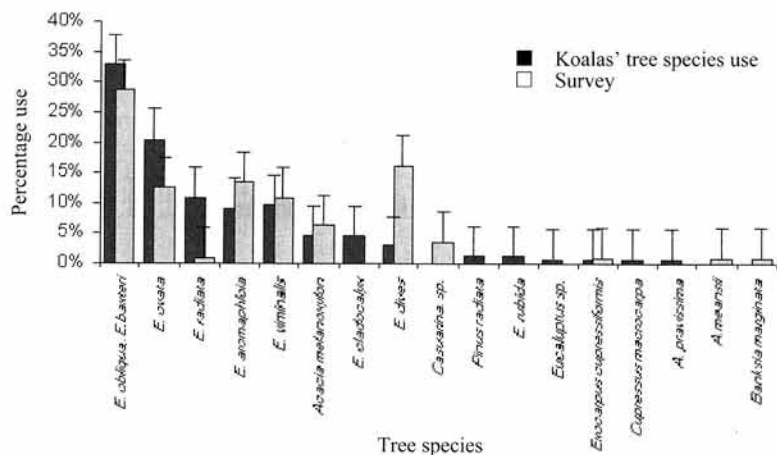


Fig. 3. Percentage of tree species used by the translocated koalas compared to percentage frequency of tree species in Lal Lal Forest. *Eucalyptus obliqua* and *E. baxteri* have been combined. Trees surveyed $n=128$; trees used by koalas $n=194$.

Creswick

Fig. 8 shows the frequencies of the DBHOB of trees surveyed and of trees koalas used in Creswick Forest. The last category includes trees with a DBHOB between 81 and 146 cm. Analysis performed on the frequencies showed that the proportions were statistically significantly different ($p=0.01$, $df=7$). Koalas mostly used trees with a DBHOB larger than the

DBHOB commonly present in Creswick. Furthermore, trees with DBHOB between 31 and 40 cm were used slightly more often than trees with DBHOB between 21 and 30 cm.

Enfield

Fig. 9 displays the frequencies of the DBHOB of trees surveyed and of the trees in which koalas were found in Enfield. The

Table 2. Descriptive statistics on the diameter of trees surveyed in the three forests.

Forest	Number of trees	DBHOB range (cm)	mean	s.d	median
Creswick	112	10-134	44.3	24.0	40.0
Enfield	64	9- 63	36.6	14.6	23.0
Lal Lal	120	8-118	32.1	16.6	30.0

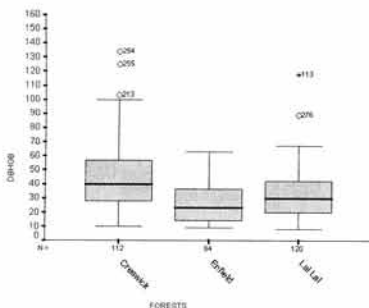


Fig. 4. Box-plot showing the median, quartiles, and extreme values of the DBHOB of all trees surveyed in the three forests. The box represents the interquartile range which contains the 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers. The line across the box indicates the median. 'O' indicate the outliers.

last category includes trees with a DBHOB between 61 and 200 cm. Koalas showed a marginal preference for trees with DBHOB class of 41-50 cm. Despite the wide range of DBHOB, the >61 category was also actively chosen given its low percentage availability at the site. However, trees with DBHOB classes of 21-30 cm and 31-40 cm were frequently chosen. The frequencies of the DBHOB of the trees surveyed and the DBHOB of the trees used by koalas were significantly different ($p < 0.01$, $df = 5$).

Lal Lal

Fig. 10 shows the frequencies of the DBHOB of trees surveyed and of trees in which koalas were found in Lal Lal. The last category includes trees with a DBHOB between 71 and 165 cm. There was a significant difference ($p < 0.01$, $df = 7$) between the frequencies of the diameters in the two groups. This is also evident from Fig. 10 where it appears that the trees in which koalas were most frequently found in Lal Lal had a DBHOB greater than the DBHOB of trees mostly available in the area. The DBHOB classes most commonly found in

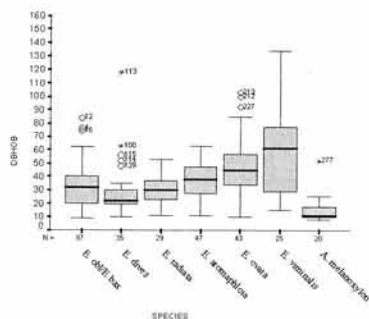


Fig.5. Boxplot showing the median, quartiles, and extreme values of the DBHOB of each species surveyed for the three forests combined. *Eucalyptus obliqua* and *E. baxteri* have been combined.

the forest were 11-20 cm and 21-30 cm, whereas the koalas were mostly found in trees with DBHOB between 31 and 50 cm.

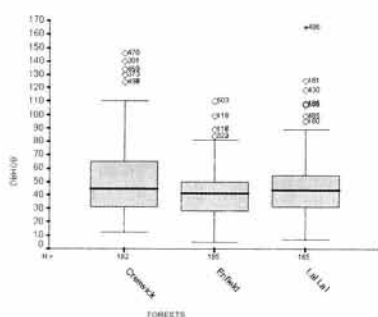
Discussion

Species

Koalas were released into State Forests, but private properties and plantations, where they could find a wide variety of tree species both native and non-native to choose for food and/or shelter, could easily be accessed. The species used by the koalas were of a wider variety than the species surveyed in the forests. During this study, koalas were occasionally observed eating leaves of trees they were using. Most of the time, however, koalas were observed sitting in the trees in the morning. Some studies dealing with Queensland koalas (Melzer *et al.* 1995; Ellis *et al.* 2002) have highlighted that often, but not always, daytime roosting is not a good indicator of diet. Previous studies on Victorian koalas (Robbins and Russell 1978; Hindell *et al.* 1985; Martin 1985; Hindell and Lee 1987, 1988), however, have shown that trees used during the day-

Table 3. Descriptive statistics on the diameter of trees used by the translocated koalas in the three forests.

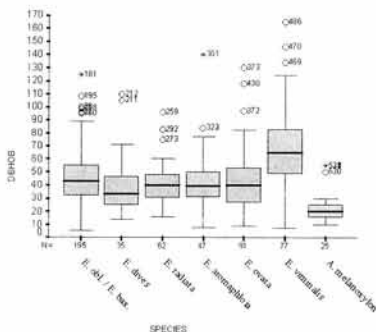
Forest	Number of trees	DBHOB range (cm)	mean	s.d	Median
Creswick	182	12-146	51.48	27.7	45.0
Enfield	185	5-110	41.0	17.6	41.0
Lal Lal	165	7-165	45.8	23.2	44.0

**Fig. 6.** Box-plot showing the median, quartiles, and extreme values of the DBHOB of all the trees used by the released koalas in the three forests.

time are also used as fodder. It is important to underline, though, that none of those studies was dealing with translocated animals. The results of this study indicate that the translocated koalas utilised a wide range of tree species even though the frequencies of some of the chosen species in the forest were low. Nevertheless, when *E. viminalis* was present (e.g. Creswick Forest) this species appeared to be highly preferred.

DBHOB

This study strongly suggests that the choice of trees by koalas is not only driven by the presence of certain species but also by tree size. It is apparent from the results that koalas mostly preferred trees of the larger average diameter than those surveyed. The preference for larger trees was reflected at a species level where koalas used larger trees amongst species. At a forest level, koalas used a tree size class proportionally greater than what was commonly available in each area. Although the results indicate that the size of trees in the forests is a possible function of the forest types and the species, the tree size chosen by the koalas is not different between forests and/or species if *E. viminalis* (the largest species) and *A. melanoxylon* (the

**Fig. 7.** Box-plot showing the median, quartiles, and extreme values of the DBHOB of each species used by released koalas. *Eucalyptus obliqua* and *E. baxteri* have been combined.

narrowest species) are not taken into account. *E. viminalis* is the species with larger tree sizes both surveyed and used by the koalas. This is probably due to the location in which larger *E. viminalis* are found. Trees in Creswick, Enfield and Lal Lal have been used for sawlog production and/or firewood. Trees with a DBHOB of 25 cm or larger are harvested for sawlogs and trees with a smaller diameter are considered residual round wood and chipped for paper or board products (Department of Natural Resources and Environment 1996a). The largest specimens are mostly found in gullies (Costermans 1994) where legal requirements prevent logging (Department of Natural Resource and Environment 1996b). Preliminary results of a survey using the Koala Habitat Atlas plot survey methodology (Phillips and Callaghan 2000) carried out in the Ballarat area by the Australian Koala Foundation (unpublished data) has indicated that the mean DBHOB of trees with koala scats present was 100.5 cm (nearly twice the mean diameter shown in this study) whilst trees without scats had a mean DBHOB of 50.2 cm. The survey was carried out mostly in unlogged areas. This could imply that, if given the opportunity, koalas would

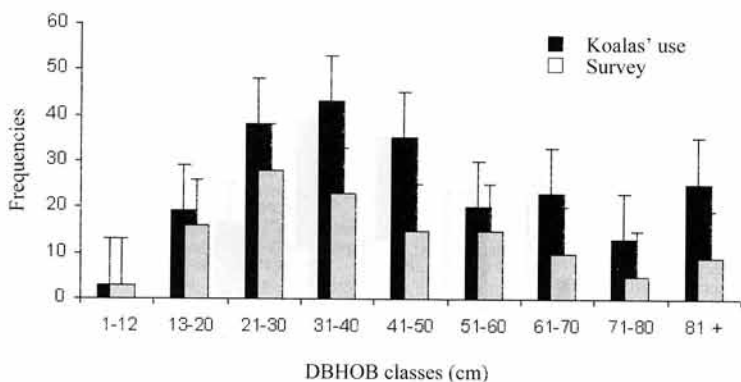


Fig. 8. Comparison of frequency distributions of DBHOB for trees in which koalas were sighted in Creswick Forest versus trees sampled along transects, all species combined.

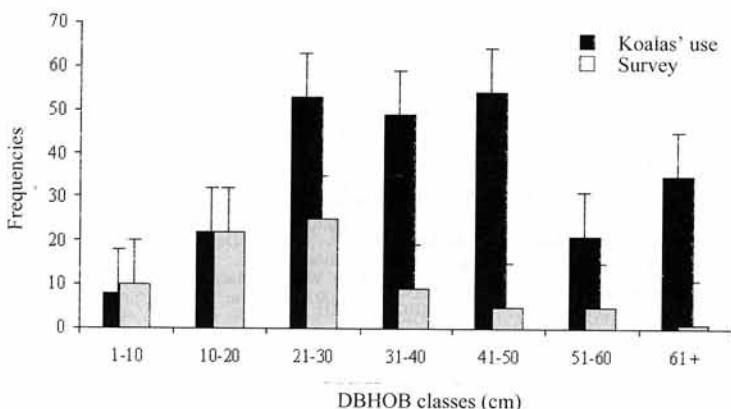


Fig. 9. Comparison of frequency distributions of DBHOB for trees in which koalas were sighted in Enfield Forest versus trees sampled along transects, all species combined.

select trees of larger size than they choose in logged forests.

Since a large trunk could mean a large crown (Niklas 1994) the selection for trees of bigger size can be linked to foliage abundance (White 1994). It appears that a link exists between adequate nutrition and successful progeny bearing (White 1994) as well as prevention of diseases (Lanyon and Sanson 1986 in White 1994). One reason for koalas' preference for larger trees is the greater access to nutrients in the soil by larger trees with larger root systems (Phillips and Callaghan 2000). However, in some mainland isolates and on islands in

Victoria where koalas have been translocated, overpopulation occurs despite extensively defoliating *E. viminalis*. Koalas still display high reproductive success (DSE 2004). Over-browsing has been linked to the high palatability of the leaves caused by land management practices that enhance fertility and moisture in the soil (Jurskis and Turner 2002).

Preference for large trees for food, shelter and nesting in tree hollows has been documented for a wide variety of arboreal marsupials (Wormington *et al.* 2003). A study in New South Wales (Kavanagh and Webb 1998) has documented the negative

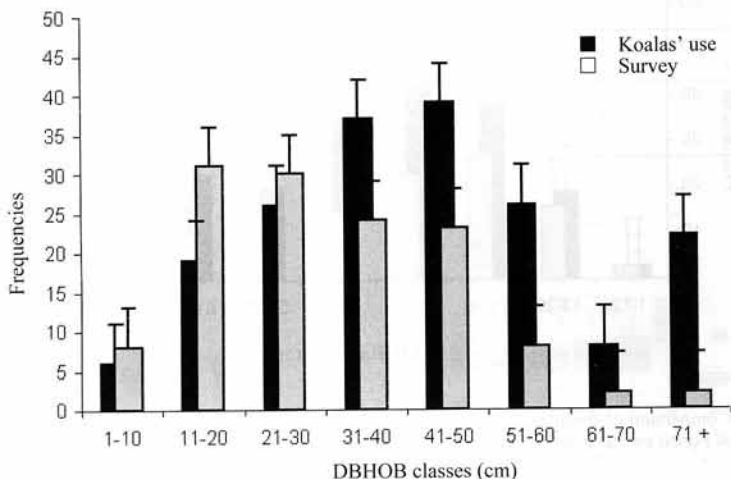


Fig. 10. Comparison of frequency distributions of DBHOB for trees in which koalas were sighted in Lal Lal Forest versus trees sampled along transects, all species combined.

impact of logging of large trees on the Greater Glider *Petauroides volans*, Sugar Glider *Petaurus breviceps* and Yellow-bellied Glider *Petaurus australis* and other species. It is possible that the removal of large trees for timber production or land development in Victoria, and more broadly in Australia, might have a future impact on the health and ultimately survival of the Koala as much as it has been shown to impact on the long term survival of hollow dependent fauna. Future studies should examine the relationship between tree size and koala density, health and survival.

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Some guidelines for the conservation of woodland insects in the Wimmera area

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Abstract

Threatened woodland habitats in the Wimmera area of western Victoria have a vital role to play in maintaining insect biodiversity within the region. This work outlines some of the important ecological processes that insects perform and provides land management guidelines for the maintenance of viable insect populations in remnants of native vegetation. Some notes are also included on a selection of typical woodland and/or grassy woodland insects that occur in western Victoria. These include brief descriptions of the listed species and some basic information on their biology. (*The Victorian Naturalist* **122** (1) 2005, 13-20).

Introduction

The plant communities that comprise the various types of woodland and grassy woodland in the Wimmera area (of western Victoria) provide food and shelter for a wide variety of insects. Trees, understorey shrubs and forbs, perennial grasses, parasitic plants and fallen timber all have a vital role to play in maintaining the biodiversity of insect populations. A healthy insect population that is balanced and

species rich ensures that pollination of native plants takes place, nutrients are recycled and that there is a reliable food supply for many vertebrate animals such as amphibians, reptiles, birds and small mammals (Crouch in prep.).

Unfortunately, since European settlement many woodland and grassy woodland insects have become restricted to remnant areas of natural habitat as a result of the widespread clearing of native vegetation for agriculture. Some species are now endangered and are only known to occur at

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