### 4.1.5 Tree Re-entry: A Juvenile-related Activity

Table 4-19 showed how frequently each tree was used. This table did not differentiate between different koalas using the same tree: it simply was a measure of how frequently particular trees were used. One of the most clearly demonstrated conclusions from this Nowendoc study was that the use of the trees in the study site by the koalas placed very little stress upon those trees. Of the 201 sightings in this section of the study, 125 were in trees which were not used again in that 12 month period. Some 65% of the trees were not re-used at all. Only 4% were used more than on three occasions of the 24 checked. It is possible to extrapolate from these figures that all 1,370 trees would be likely to be visited in 235 days. If one assumes that the proportion of re-entry observed was a representative sample of the behaviour of the koalas, they could live in the study site and visit the individual trees quite infrequently. Most trees would be grazed only two or three times annually. Re-entry was found to be quite uncommon: it would be difficult to conclude that the few re-used trees were "preferred" because of such an important daily need as feeding. These few re-entered trees seemed to be of little consequence for food.

If one examined the ten most re-entered trees, as shown in Table 4-20, there was nothing remarkable about their species format. Where the total proportion for all trees on the site was:

| **Eucalyptus acaciiformis** | **Eucalyptus stellulata** | **Eucalyptus pauciflora** |
|---|---|---|
| 0.64 | 0.30 | 0.06 |

for all koala-used trees the proportion was:

| **Eucalyptus acaciiformis** | **Eucalyptus stellulata** | **Eucalyptus pauciflora** |
|---|---|---|
| 0.64 | 0.27 | 0.09 |

and for the ten re-entered trees this proportion was:

| **Eucalyptus acaciiformis** | **Eucalyptus stellulata** | **Eucalyptus pauciflora** |
|---|---|---|
| 0.70 | 0.30 | 0.00 |

and given the small sample size, one must conclude that there was no significant difference between this group of ten trees and either of the other two groups.

The re-entered trees were slightly taller than the other koala-used trees, having a mean height of 23 m. as against 20 m., and none of them were as small as the shortest in the range of koala-used trees.

TABLE 4-19

RECURRENCE PATTERN IN TREE USE

| LOCATION | NUMBER OF ANIMALS | RE-ENTRY FREQUENCY IN 12 MONTH STUDY 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lower Flat | 16 | 1 | 11 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Middle Rise | 32 | 3 | 22 | 1 | 2 | 1 | 1 | 0 | 1 | 0 | 1 |
| Back Fence | 20 | 5 | 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Back Rise | 47 | 2 | 33 | 10 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| Creekside | 16 | 3 | 6 | 5 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Far East | 60 | 0 | 41 | 10 | 5 | 1 | 3 | 0 | 0 | 0 | 0 |
| TOTAL | 201 | 14 | 125 | 31 | 11 | 2 | 6 | 0 | 1 | 0 | 1 |
| Proportions of Total Re-entries | | .07 | .65 | .15 | .05 | .01 | .03 | .00 | .00 | .00 | .00 |

Table 4-20.

RE-ENTERED TREES' PROPERTIES

Of 196 trees entered by koalas, 186 were used 0, 1, 2 or 3 times only over the year-long 33 observations programme. Only 11 trees were entered 3 times.

For the ten most frequently re-entered trees, the following data applied:

| AREA | TREE | SPECIES | ENTRY FREQUENCY | NO. OF DIFFERENT ANIMALS | OVERNIGHT STAYS | HEIGHT (m.) |
|---|---|---|---|---|---|---|
| MR | 9 | **E. acaciiformis** | 4 | 4 | 0 | 19 |
| MR | 41 | **E. acaciiformis** | 7 | 6 | 0 | 27 |
| FE | 42 | **E.stellulata** | 5 | 4 | 0 | 23 |
| MR | 45 | **E. acaciiformis** | 9 | 2 | 1 | 13 |
| FE | 65 | **E.stellulata** | 5 | 2 | 0 | 27 |
| MR | 67 | **E. acaciiformis** | 5 | 4 | 0 | 24 |
| FE | 72 | **E.stellulata** | 5 | 3 | 0 | 23 |
| FE | 105 | **E.acaciiformis** | 4 | 1 | 1 | 18 |
| CK | 120 | **E.acaciiformis** | 5 | 1 | 0 | 14 |
| CK | 128 | **E.acaciiformis** | 5 | 1 | 0 | 36 |

(7 acaciiformis and 3 stellulata, no pauciflora) Mean Height 23 m. and Mean Number of Different Animals was 2.8)

# Long term continuous use of a single tree was unusual.
# Few animals re-used any particular tree to an appreciable amount
# Re-used trees did not belong to any particular species. They were taller than the mean size; their smallest member was 7 m. taller than the smallest ever entered by the koalas. Their location within the study site seemed unremarkable.

These ten trees were used by a mean of 2.8 different koalas, but the mean for all koala-used eucalypts was only 1.4. Since so many of the other 186 trees were visited only once (125 of them, see Table 4-20) it appeared that the same pattern of use was continued with these few more frequently re-used trees, viz. the probability that the re-entering koala would be a previous user was no higher than for the other trees. The frequently-used trees were not the exclusive territory of more dominant koalas. Though these trees were the most frequently used, the koalas were no more likely to remain overnight in these trees than in any others, and the distribution of the ten trees within the site was wide (though none were on the Back Rise site, the Lower Flat site or the Back Fence.)

If one examined which animals used these ten trees, some insight into the location of these particular trees was gained. In Figure 4-12, where the ten most frequented trees were indicated, six of those trees were centrally located. The other four were used by juveniles or animals having particular attributes. These attributes are recorded in Table 4-21. The most likely attributes of these trees, contributing to their re-use appeared to be:

(i) their central location,

(ii) their above average size (mean=23 m. where n=10, and mean for all koala trees =20 m. where n=197), and possibly,

(iii) suitable configuration for concealment.

All of the centrally-located frequently-used trees had substantial mistletoe growth well up in their branches (as did very many of the site's eucalypts). They were surrounded by numerous trees of similar heights, which also had mistletoe growths.

Table 4-21 records those trees in which dependent juveniles were seen accompannying females . Only three of the 22 trees used by these juveniles were from the most frequented trees of Table 4-20. The animals were found in peripheral and central quadrats, but they appeared less likely to move substantial distances overnight. Thus, though the dependent juveniles lacked mobility, this did not appear to be a major reason why there were some trees which were re-entered more frequently. However, the juveniles' diminished mobility did contribute to the above average use of some quadrats.

FIGURE 4-11

MAP OF THE MUKKI CREEK STUDY AREA

(ten most frequented trees indicated)

NOTE: 120 used only by the introduced animal 0102.
128 used only by the one juvenile C19j.
45 used by the juveniles E44j and E45j.
105 used by E53a, an infrequent adult visitor.
9, 41, 42, 65, 67 and 72 are centrally located, and possess suitable concealment configurations with mistletoe.

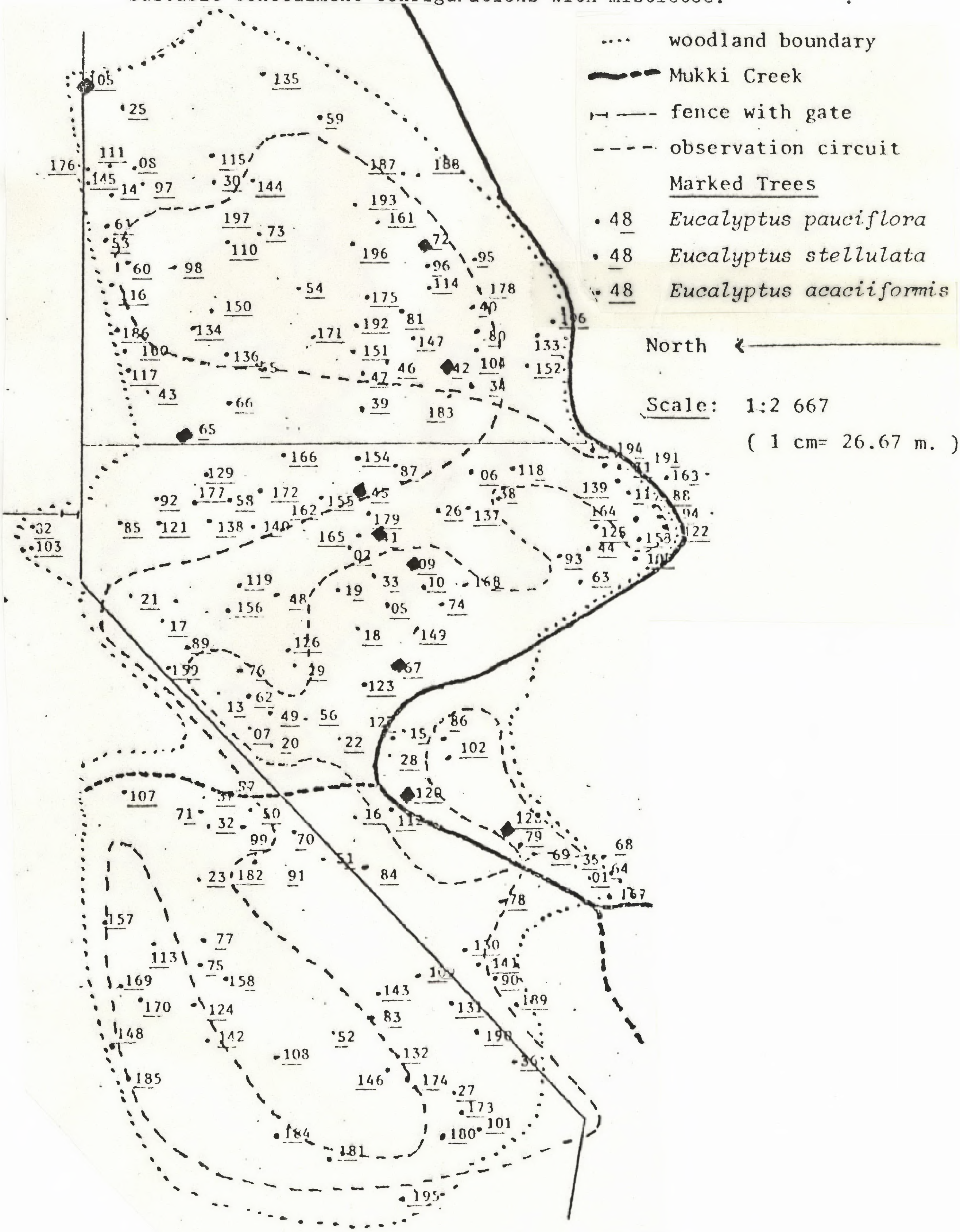


TABLE 4-21

LOCATIONS OF JUVENILE KOALAS

| ANIMAL | DATE | TREE | SPECIES | QUADRAT | DATE | TREE | SPECIES | QUADRAT |
|---|---|---|---|---|---|---|---|---|
| Z155bj | 24/7 | 155 | E. ac. | C5 | | | | |
| (with | 5/8 | 162 | E. ac. | C5 | | | | |
| A33) | 18/8 | 166 | E. ac. | C4 | | | | |
| | 1/9 | 169 | E. st. | A9 | | | | |
| | 24/9 | 173 | E. st. | D10 | 25/9 | 173 | E. st. | D10 |
| | 1/10 | 181 | E. st. | C10 | 2/10 | 184 | E. st. | C10 |
| AG187bj (with C23) | 13/10 | 192 | E. ac. | C3 | 2/10 | 187 | E. st. | D2 |
| AG188bj (with C39) | 13/10 | 72 | E. st. | D2 | 2/10 | 188 | E. ac. | D2 |
| E53bj | 2/1 | 53 | E. ac. | A2 | | | | |
| (with | 16/1 | 60 | E. ac. | A3 | 17/1 | 61 | E. ac. | A2 |
| E53a) | 10/3 | 67 | E. ac. | D6 | | | | |
| B34cj | 15/11 | 34 | E. st. | D4 | | | | |
| (with | 26/11 | 37 | E. ac. | B7 | | | | |
| B34b) | 12/12 | 41 | E. ac. | D5 | | | | |
| | 2/1 | 47 | E. ac. | C3 | | | | |
| | 10/3 | 84 | E. ac. | C8 | | | | |

Table 4-22 extracts from the ten trees of Table 4-20 those used by only one koala. When the remaining six trees were examined, 23 of the 31 visits associated with those trees were by koalas which were dependent. They were either females with dependent juveniles, dependent juveniles on backs or bellies, or juveniles still found in the company of females. The introduced zoo animal behaved in the same manner as these animals, in spite of its two year age. It was quite fixed, frequently in close proximity to other adults and often found out from the concealing mistletoe.

The "popularity" of these six trees did not appear to be the cause of the behaviour of these dependent koalas. On the contrary, the koalas' relative fixedness appeared to be the major reason for the re-use of those trees. The very small number of "favoured" trees was an important finding in this study: it established that the location of such trees must be of little significance for zoo feeding programmes.

Figure 4-12 traces the increases in the number of trees which were tagged because a koala had been seen in them. It also shows the proportion of trees re-entered monthly. If the koalas used only a small proportion of the trees on the site, one might have expected this re-entry proportion to have gradually increased as all such trees became completely tagged. This was not the case. The re-entry proportion ranged between 15 and 50% and demonstrated no clear relationship to the number of tagged and entered trees. The number of trees identified as used by koalas never reached a stage where the koalas departed from their practice of predominantly entering trees which had not been previously used. This evidence suggested that the koalas could use every **Eucalyptus** tree on the site.

## TABLE 4-22

## A COMPARISON OF THE KOALAS USING SIX "POPULAR" TREES

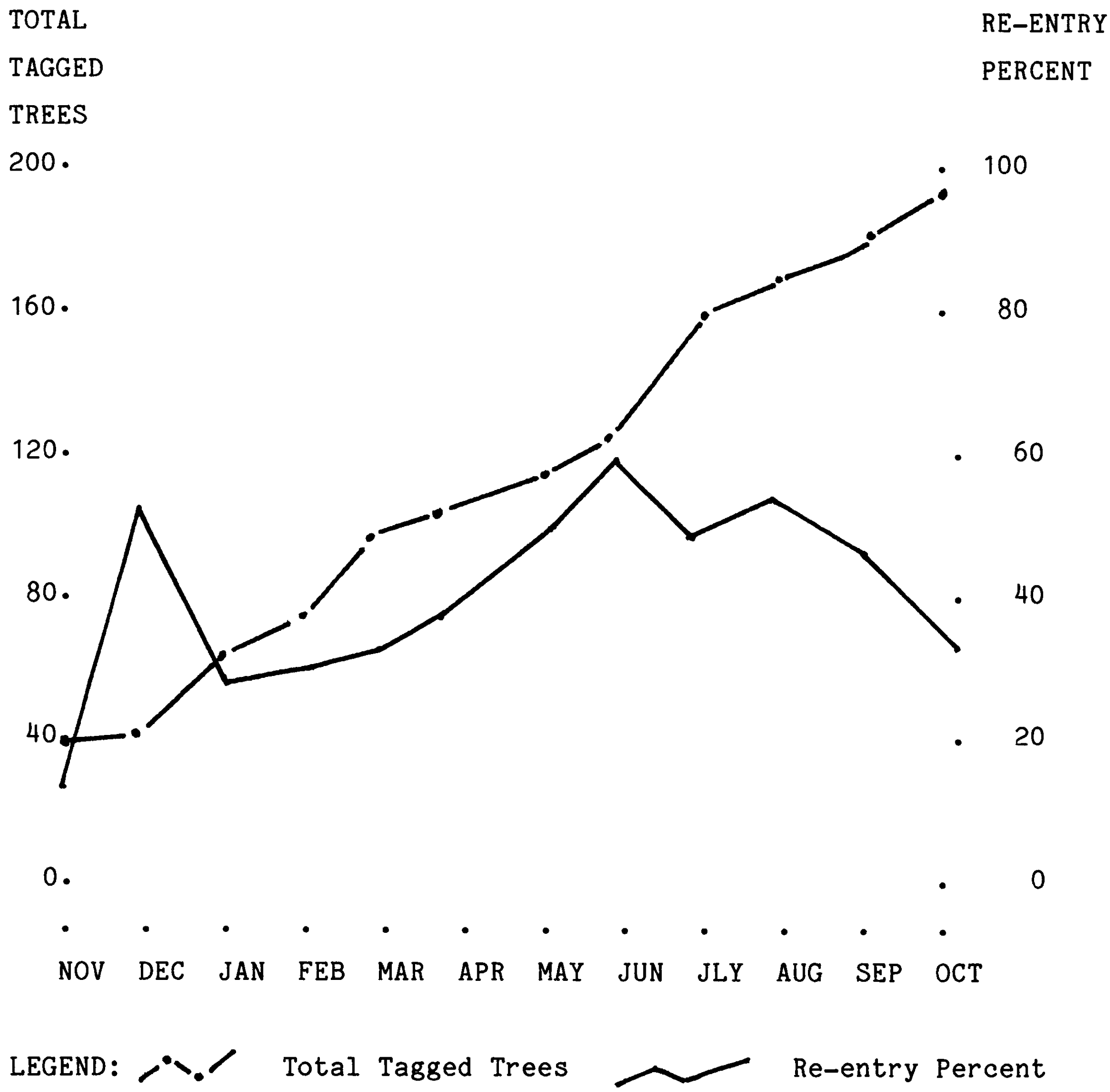
(These trees were identified in Table 4-20 as being among the ten most frequented trees and as being used by more than one koala)

| TREE | SPECIES | ANIMAL | DATE | QUADRAT | NO. OF VISITS | NO. OF KOALAS |
|---|---|---|---|---|---|---|
| 9 | **E. acaciiformis** | C38 | 25/3 | D5 | 4 | 4 |
| 9 | **E. acaciiformis** | C23 | 16/5 | D5 | 4 | 4 |
| 9 | **E. acaciiformis** | A33 | 28/5 | D5 | 4 | 4 |
| 9 | **E. acaciiformis** | E45j | 23/6 | D5 | 4 | 4 |
| 42 | **E. stellulata** | A33 | 12/12 | D3 | 5 | 4 |
| 42 | **E. stellulata** | C38 | 16/1 | D3 | 5 | 4 |
| 42 | **E. stellulata** | C38 | 23/6 | D3 | 5 | 4 |
| 42 | **E. stellulata** | C23 | 9/6 | D3 | 5 | 4 |
| 42 | **E. stellulata** | O102 | 24/7 | D3 | 5 | 4 |
| 41 | **E. acaciiformis** | B34a | 12/12 | D5 | 7 | 4 |
| 41 | **E. acaciiformis** | B34a | 23/4 | D5 | 7 | 4 |
| 41 | **E. acaciiformis** | E45j | 11/2 | D5 | 7 | 4 |
| 41 | **E. acaciiformis** | C38 | 24/3 | D5 | 7 | 4 |
| 41 | **E. acaciiformis** | A33 | 14/4 | D5 | 7 | 4 |
| 41 | **E. acaciiformis** | A33 | 25/4 | D5 | 7 | 4 |
| 41 | **E. acaciiformis** | A33 | 7/7 | D5 | 7 | 4 |
| 65 | **E. stellulata** | C39 | 30/1 | B4 | 5 | 2 |
| 65 | **E. stellulata** | C39 | 11/2 | B4 | 5 | 2 |
| 65 | **E. stellulata** | C39 | 24/3 | B4 | 5 | 2 |
| 65 | **E. stellulata** | C39 | 23/4 | B4 | 5 | 2 |
| 65 | **E. stellulata** | D28 | 28/5 | B4 | 5 | 2 |
| 67 | **E. acaciiformis** | C38 | 11/2 | D6 | 5 | 4 |
| 67 | **E. acaciiformis** | E53bj | 10/3 | D6 | 5 | 4 |
| 67 | **E. acaciiformis** | C23 | 23/4 | D6 | 5 | 4 |
| 67 | **E. acaciiformis** | E45j | 28/5 | D6 | 5 | 4 |
| 67 | **E. acaciiformis** | E45j | 7/7 | D6 | 5 | 4 |
| 72 | **E. stellulata** | A33 | 11/2 | D2 | 5 | 3 |
| 72 | **E. stellulata** | A33 | 21/2 | D2 | 5 | 3 |
| 72 | **E. stellulata** | C40 | 23/6 | D2 | 5 | 3 |
| 72 | **E. stellulata** | C40 | 7/7 | D2 | 5 | 3 |
| 72 | **E. stellulata** | C39 | 13/10 | D2 | 5 | 3 |

NOTE: Underlined animals were not independent adults.
Quadrats C4, D5 and E5 were used all four seasons.
Quadrats B9, C4, D3 and D5 were visited at least nine times
Quadrats B9, D3 and D5 were used by at least seven koalas

FIGURE 4-12

TREE RE-ENTRY AND TOTAL NUMBER OF ENTERED TREES




Total tagged trees: 40 at November start, 197 at October conclusion

Mean re-entry : 113 of 305 sightings (37%)

Though few koalas remained in the same tree overnight, re-entry was more likely to occur within the next four weeks following a koala's departure. Table 4-23 shows that almost all animals were involved in re-entry behaviour. This table includes the 9 overnight checks as well as the 24 routine visits. Of the 53 re-entries, 33 occurred within the next 30 days. The periods between these re-entries ranged from one day to 159 days. The mean was 36 days. Because continuous use only occurred infrequently, the impact of koala grazing was insufficient at Nowendoc for many trees (even if re-entered) to be eaten bare. Each area contained some trees which were re-entered.

Any summary of the re-entry findings must stress that re-use of **Eucalyptus** trees by the same koala, or entry by any koala into a tree previously occupied by another koala were both less frequent events than the entry of a previously unused **Eucalyptus** tree. The re-entered trees were drawn from all the species present in the same proportions as the trees occurred on the study site, however the most frequently re-entered trees tended to be slightly taller than the average, and to have a smaller size range (since none were below 12 m.). They were usually more centrally located, and contained good concealment configurations. They were not usually the territory of particular koalas. Their higher frequency in re-use appeared to be linked to the lesser mobility of those koalas which were not completely independent. Though these animals were unlikely to remain in the trees overnight, they seldom moved far and thus were more likely to return. Such returns were less common as the time since first use progressed beyond 30 days. Re-entry data supported an assertion that all trees on the site were potentially usable for the koalas.

TABLE 4-23

PERIODS BETWEEN TREE RE-ENTRY FOR INDIVIDUAL ANIMALS

| AREA | TREE | SPECIES | ANIMAL | PERIODS BETWEEN RE-ENTRY |
|---|---|---|---|---|
| BR | 36 | E. ac. | C36a | _17_ |
| BR | 75 | E. ac. | C36bj | 96, 26 |
| BR | 77 | E. st. | C36bj | _1_ |
| BR | 113 | E. st. | 0102 | 75 |
| BR | 1426 | E. ac. | D28 | 26 |
| BR | 146 | E. st. | C36a | 21 |
| BR | 173 | E. st. | A33 | 6 |
| CK | 120 | E. ac. | 0102 | 28, 26, _13_ |
| CK | 127 | E. pa. | B34a | 38 |
| CK | 128 | E. ac. | C19j | _10_, 41, 16, 25 |
| CK | 167 | E. ac. | C19j | 69 |
| LF | 44 | E. ac. | E44j | 28, _12_ |
| LF | 93 | E. ac. | E44j | 80 |
| LF | 163 | E. pa. | 0102 | 57 |
| MR | 41 | E. ac. | A33 | 11 |
| MR | 45 | E. ac. | E45j | 49, 40, 56, _13_, 37, 9 |
| MR | 45 | E. ac. | E44j | _1_ |
| MR | 67 | E. ac. | E44j | 40 |
| MR | 74 | E. ac. | C36a | 18 |
| BF | 177 | E. ac. | 0102 | 6 |
| FE | 30 | E. ac. | C38 | 2 |
| FE | 39 | E. ac. | C39 | 79, 11 |
| FE | 42 | E. st. | C38 | 159 |
| FE | 47 | E. ac. | B34b | 15, 35 |
| FE | 60 | E. ac. | E53a | _1_ |
| FE | 65 | E. st. | C39 | _12_, 42, 30 |

LEGEND: Underlined periods may have been continuously occupied.
Data based upon 33 observations over 12 month period. Maximum elapsed time between any 2 observations , 17 days.

TABLE 4-23 (Continued)

PERIODS BETWEEN RE-ENTRY FOR INDIVIDUAL ANIMALS

| AREA | TREE | SPECIES | ANIMAL | PERIODS BETWEEN RE-ENTRY |
|---|---|---|---|---|
| FE | 72 | E. st. | A33 | 10 |
| FE | 72 | E. st. | C39 | 14, 98 |
| FE | 73 | E. ac. | C23 | 28, 119 |
| FE | 97 | E. ac. | E45j | 9 |
| FE | 98 | E. ac. | C23 | 84 |
| FE | 105 | E. ac. | E53a | 2, 23, 151 |
| FE | 176 | E. ac. | C40 | 1 |

LEGEND: Underlined periods may have been continuously occupied.
Data based upon 33 observations over 12 month period. Maximum elapsed time between any 2 observations , 17 days.

ANALYSIS:

53 Re-entries

Range 1-159 days

Mean period between re-entry 36 days

31 trees used, of which 22 (71%) were E. ac., 7 (23%) were E. st. and 2 (6%) were E. pa.

All animals except D35 (which was only seen on 8 occasions) were involved in re-entry.

Each animal re-entered between 1 and 4 times in the 33 observations.

Mean number of re-entries was 2.3 per koala.

TREE RE-ENTRY FREQUENCY

| | |
|---|---|
| 0-10 days | 12 times |
| 11-20 days | 11 times |
| 21-30 days | 10 times |
| 31-40 days | 4 times |
| 41-50 days | 4 times |
| 51-60 days | 2 times |
| >61 days | 10 times |

4.1.6 Environmental Effects

A number of preceding results were related to environmental effects, and have been summarised here.

Figure 3- 2 demonstrated that the only seasonal change in the tree entry preferences was an increase in the popularity of **Eucalyptus stellulata** during September to November.

Figure 3- 8 indicated that the koalas tended to select the same range of trees, with respect to height, regardless of season. They were also consistently located at similar heights up these trees year-round.

Table 4-11 and Figure 3-10 demonstrated that, though few quadrats were in use for all four seasons, there was occupation of all areas in the site during all four seasons.

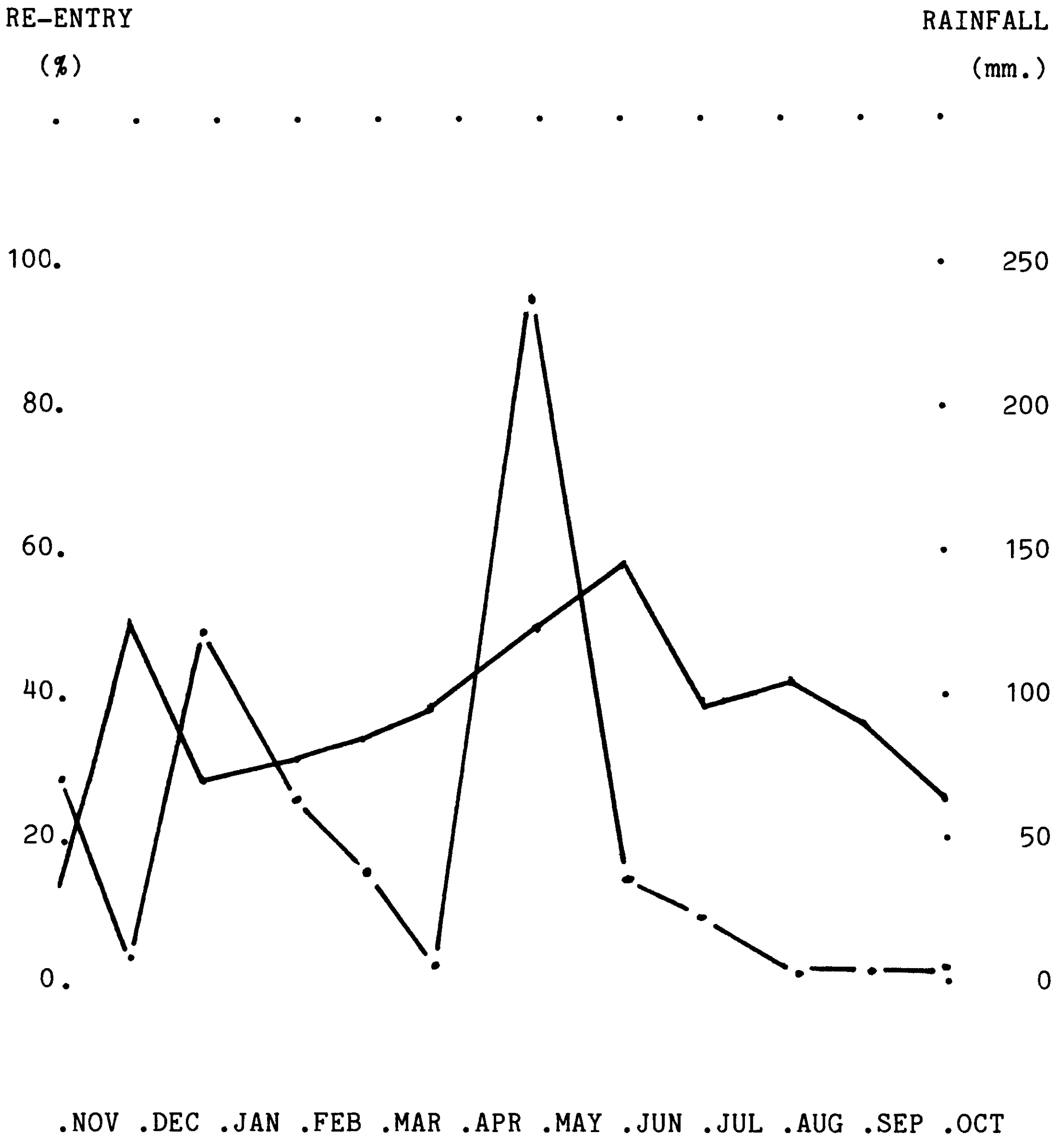
Though the area per animal varied throughout the year, as shown in Figure 3-11, no seasonal trends were evident, nor did the area correlate satisfactorily with temporary improvements in leaves following rain. The number of animals on site was similarly unaffected by rainfall, as shown in Figure 4- 6.

Field notes drawn from particular weather conditions, as recorded in Tables 4-13 to 4-17 all indicated that the koalas did not select **Eucalyptus** trees in response to environmental stress, though they did display some postural responses. They also showed no tendency to locate within the trees so as to minimise environmental stress. Even a bushfire which damaged trees to a height of four metres did not change the pattern of tree use of the koalas.

The overall model arising from this study suggested that these Nowendoc animals' year-round behaviour proceeded with little relationship to season or weather. To complete this evidence, Figure 4-13 indicated that the amount of re-entry fluctuated considerably throughout the year. When interpreting this re-entry graph, one must consider that the number of tagged trees rose from 32 to 197 during this period, making the probability of re-entry higher as the year progressed. Re-entry was always less likely than entry of a different, previously unused tree. No clear relationship between re-entry and rainfall could be established. The koalas seemed no more likely to re-enter the trees following drought stress on the leaves or improvement after rain. This re-entry pattern accorded with the previous evidence that season and weather had very little effect on the utilization of **Eucalyptus** trees by koalas.

FIGURE 4-13

CHANGES IN RE-ENTRY AND RAINFALL OVER A 12 MONTH PERIOD




Correlation= 0.02 LEGEND RAINFALL PERCENTAGE RE-ENTRY

## 4.2 CONCLUSIONS

### 4.2.1 Concerning Intra-species Selection Of **Eucalyptus** Trees

While numerous researchers have attempted to focus their attention upon chemical factors which might indicate why some trees within a species of **Eucalyptus** appear to be more favoured by koalas, this study demonstrated that such an approach cannot completely explain tree selection by koalas. The most important aspect of tree selection demonstrated by this study was that the extent of re-use of "favoured" trees was quite small. Overnight re-use of the same tree was less than 10% (n=81 overnight observations) while the re-use of a tree within 12 months (based upon 211 observations at fortnightly intervals) was only 34%. This data was extracted from Table H- 9. Most trees entered by koalas had not been used by any koalas for a very considerable period of time. The factors which influenced tree selection, whether on re-use or on entering a tree previously unused for a long time, were clearly not all chemical.

This study substantiated that the favoured trees within any one species had at least three non-chemical features. These were found to be:

* their size,
* their location with regard to the perimeter of the study site, and
* the availability of concealment positions (commonly using mistletoe) within the tree.

The preferred size was above 7 m. Koalas made very little use of the lower parts of the taller trees, and seldom entered trees of less than 7 m. Central location was a characteristic of the preferred trees, regardless of which of the three parameters one considered. (The three parameters of preference considered were:

* use throughout the year,
* use by more than one particular koala, and
* entry on more than one occasion by any koala.)

Unlike zoo animals which may rest in locations exposed to human observation, most of the free-roaming koalas in this study site rested in concealed, elevated positions. Resting, not feeding, was the dominant koala activity day and night.

Tree entry was also influenced by the location of other koalas. Generally adult koalas were not found within 50 m. of each other. Juveniles did not appear to regard such distance considerations when tree-entering.

There was no evidence of "dominant" animals having any territory of preferred trees. Though there was little opportunity to observe this displayed through inter-animal confrontations (because of the cryptic response to human observation) the irregular pattern of tree occupation by the koalas clearly demonstrated that the animals' locations were more influenced by sequential entry into the study site than by displacement of "lower order" animals. The solitary behaviour of free-roaming koalas appeared to be a factor at least as important as the chemical preferences concerned in intra-specific tree selection.

Tree selection was also affected by the large amount of local movement displayed by the koalas. The independent adult animals were particularly unlikely to remain in any tree beyond one night. Such persistent transfers clearly indicated that favoured trees must play only a minor role in food preferences. Any suggestion of a critical role, by way of provision of some vital chemical, occasionally required in small quantities, seemed doubtful. The extent of favored tree re-use by some of the koalas was very small indeed. What re-use there was, generally occurred within 4 weeks of the initial entry.

Selection of trees within any species appeared to be unchanged by seasonal conditions. Some behaviour of the animals accorded with published observations of sanctuary koalas, in that the behavioural repertoire of the animals seemed both limited and simplified.(Smith 1979c). Climatic considerations only affected the posture of these free-roaming koalas, not their disposition within the trees. This contrasted with Degabriele's earlier observations. (Degabriele 1973)

### 4.2.2 Concerning Inter-species Selection Of **Eucalyptus** Trees

The same three parameters of preference were used in the comparison between local species as were used for intra-specific comparisons,viz. use by more than one animal, use on more than one occasion, and year-round use.

Regardless of species, preferred trees had both central locations within the study site and substantial available concealment. They all exceeded 7 m. height. Regardless of species, re-use of a tree was an uncommon event. Adult koalas usually occupied trees such that no two adults were within the same 50 $m^2$ quadrat. The tendency for adult koalas to transfer nightly between trees was displayed for all species of **Eucalyptus** on the site.

The koalas displayed a tendency to utilise **Eucalyptus pauciflora** only in proportion to the frequency of that species on the site. The relative preference of the two non-pauciflora species available varied throughout the year. Consequently the study supported previous claims that local preferences existed between available **Eucalyptus** species, but distinguished between some persistent preferences and others which were seasonal.

The preferences for certain species were not exhibited uniformly by all koalas. This most commonly exhibited itself in the proportional use of each species by the koalas. Most animals did in fact enter all available species at some time during the study. Animals did not persist with any species for extended periods. Most nights they changes trees. The tree selected was more likely to be entered having regard to the location of other adults than any apparent preference to continue using a certain species. The koalas were likely to remain on the site for long periods, once they had entered it. They did not move from the site in groups larger than one female parent with a juvenile. Simultaneous entry or exit by the whole colony was never observed, nor was there any indirect evidence of such co-ordinated movement. The changes in **Eucalyptus** preferences did however tend to be a more general behaviour. While the proportional use of the different **Eucalyptus** species differed between individual, the year-round minor use of **Eucalyptus pauciflora** and the seasonal change in preference from **Eucalyptus stellulata** to **Eucalyptus acaciiformis** were common features of all the free-roaming koalas at Nowendoc.

4.2.3 The "Prudent Folivore" Model Appraised

A number of the findings from this study may be applied to Clarke's "Prudent Folivore" model, which is set out in Appendix D. The relationships of the six-point model and this study were as follows:

A). The existence of no single feature determining the suitability of leaf for all koalas.

This was supported. Some of the koalas had definite variations in their preferences. Factors both external to the individual koala (such as the location of a tree relative to another adult koala, or to the wooded perimeter) and unrelated to leaf chemical qualities (such as whether the koala had entered the site on the preceding night) also influenced which leaf was consumed.

B). The avoiding of leaf substances, rather than the search for favoured ones.

Only indirect evidence was available, since searching behaviour and other leaf-eating activity were only infrequently observed. Those koalas which were observed feeding continued eating almost all the leaves on any branch where they began. Some leaves were dropped, but this did not follow deliberate sniffing or expulsion from the mouth, and consequently was interpreted as unintentional rather than any purposeful selection by the animal. The common practice of moving from each tree nightly appeared to make it quite unlikely that the koala had completely searched the tree, given the 20 m. mean height of the study site trees. It may be possible to explain the refusal of zoo koalas to eat leaf as related to non-chemical constituents of the koalas' environment. These constituents may have no counterpart in the free-roaming koalas' environment. Stress caused by the proximity of other koalas, or of humans may be such an environmental feature. One reaction to such stress may be the cryptic response exhibited by the Nowendoc animals. Possibly failure to feed is a related response. Neither the persistent searching of a tree's leaves, nor the rejection of leaf within a tree was observed during the study of the Nowendoc animals. Since so few trees were occupied for extended periods, one might conclude that, if the koalas were indeed searching for a preferred chemical, they seldom found it. If they were attempting to avoid any substance, it must have been very common. In review, neither searching nor avoiding appeared to occur.

C). The desirability of certain leaf may depend upon the koala's recent gut experience, its enzyme population and the availability of suitable metabolites.

The successful translocation of the zoo animal ( which is described in Appendix C (b)) involved an animal being moved into an area where none of the **Eucalyptus** species available had been previously encountered. This animal translocated without apparent difficulty. The frequency with which all the Nowendoc koalas changed the species of **Eucalyptus** which they entered, rather than persisting with any single species, also appeared to indicate that this section of the model was incorrect.

D). Confinement of koalas does not give the opportunities for such fastidious leaf choice as is available to a solitary free-roaming animal.

The importance of the solitary lifestyle may be at present poorly understood by sanctuary staff. It may be the reason why so few bush-born koalas have been successfully introduced to zoos, while those koalas born in zoos have more successfully accommodated to the stress of close proximity. Whether the stress resides principally in the proximity of human or other koalas, or both, is presently only a matter of conjecture. Undoubtedly the solitary nature of the free-roaming koala affords a wide selection of leaf. It may also provide suitable defence against human observation and predation. However the very frequent changes of trees, and the short periods spent even in the most favoured **Eucalyptus** would appear to infer that, if leaf preference was the reason for persistent use of a single tree, the koalas seldom encountered such leaves. An alternative explanation might be that tolerance of the proximity of other koalas was minimised by these frequent relocations. If a reduction in the tendency to feed was a koala's response to the proximity of other koalas, then stress reduction, rather than increased leaf choice, would supply a superior explanation of the koala's solitary lifestyle.

E). Continuous consumption of minor amounts of novel feed ensures that a more varied enzyme population is maintained than would be likely from constant browsing of a single **Eucalyptus** species.

This study verified that free-roaming koalas did not persist with any single **Eucalyptus** species for extended periods. Although the study did not provide evidence of the consumption of novel browse, there was ample published to substantiate its occurrence. (Nolan 1968: Foster 1975: Gall 1976: Degabriele 1978: Veitch 1980). There was no attempt in this study to examine gut enzymes, however it would appear that the same comments as recorded in Chapter 4.2.3(C) apply, viz. the successful translocation of the zoo koala and the lack of persistent feeding upon any single **Eucalyptus** species indirectly indicated that this section of the "Prudent Folivore" model was probably incorrect. An alternative interpretation in terms of stress upon confined koalas might be advanced here. The frequent changes in preferred food exhibited by the zoo koalas may be a variation in the failure to feed behaviour, which was postulated in Section 4.2.3 (B) of this chapter.

F). Only a limited amount of time is available during which a koala must adapt to feed variations.

This limitation was claimed to be related to the minor amounts of body fat and the koala's slow digesta passage. The same evidence which was outlined previously in Section 4.2.3 (C) and (E) of this chapter indicated that this section of the model was incorrect. There appeared to be an assumption subconsciously made by zoo staff that bringing fresh leaf to confined koalas was equivalent to the koala entering a different tree. Further, they assumed that not eating the available leaf was equivalent to the koala preferring to enter another tree. These two assumptions failed to acount for the possibility that koalas may move from trees for reasons unrelated to leaf qualities. Avoiding other adult koalas in such close proximity appeared to be one factor influencing the movement of the Nowendoc koalas: entering concealment distant from the periphery of the study site was another. Confined animals were unable to effect either change in the small enclosures often used in Australian zoos and sanctuaries. The provision of such high quality browse may be a means of reducing the failure to feed response. In the free-roaming situation, such high quality browse may not be required since other means of stress-reduction were available.

## 4.3 RECOMMENDATIONS FOR FURTHER RESEARCH

Zoo koalas might be described as sleepy, domesticated animals having a poor breeding record. They may be maintained in exhibition enclosures by procedures to circumvent the fastidious feeding behaviours which it has been claimed these marsupials have demonstrated. This fastidious feeding may arise from stress caused by the close proximity of other koalas, or of human observation. In the Nowendoc study, the cryptic response demonstrated by the koalas was apparently a temporary one caused by human observation. From overnight observations, a total number of 68 animals left the site during nights which followed the author's routine checks. On the same nights 64 animals entered the site. If the response to the author's intrusion had been enduring, rather than temporary, one would have anticipated that many more animals would have left. Some of the study's limitations could serve as useful foci for further research. This study has not examined chemical tests on leaves, however the possibility that grazing increases allelochemic production could now be researched. This study was unable to produce detailed observations of leaf selection or feeding behaviour of wild koalas. No evidence presently available directly links crowding with fstidious feeding in koalas. No relationship between individual spacing and the frequent relocation of koalas has been established by this study. It would be beneficial to examine whether the fastidious feeding of confined animals is principally related to either human observation or proximity of other adult koalas. This would be desirable knowledge should one intend to depart from the current practice of maintaining koala exhibits from zoo-bred animals. It would also assist in the successful assistance of injured wild koalas where current practice has been to quarantine such animals although they then experienced considerable human contact. This practice has seldom been successful. (Clarke 1980). A relatively simple experimental procedure would be to persuade a zoo to provide temporary separate enclosures for all its adult koalas , then to monitor the relative fastidiousness of these animals compared to when they were corporately enclosed.

The successful translocation of the zoo animal into **Eucalyptus** trees of a species previously encountered, served as a useful pilot model. It would be appropriate to attempt the movement of a larger sample of animals using the same stress-reducing procedures and deliberately mismatching **Eucalyptus** species. The success of this procedure with a statistically significant sample would greatly strengthen the concept of stress as a more significant factor than feed quality. A related experiment which would be valuable, would be to recapture the zoo-bred koala from Nowendoc and relocate it to the small enclosure situation to see if the fastidious feeding behaviour and tolerance of other adults' proximity were demonstrated.

A useful follow-up project would be to examine the possibility that koalas leave trees which they have grazed upon because their grazing increases the amount of unpalatable secondary substance(s) in the leaves. This effect may be independent of the species eaten. It could indicate why the koalas' solitary lifestyle has evolved, and may show why earlier work on allelopathy (where researchers focused upon species, not individual trees) was unsuccessful in explaining koala behaviour.

It would be appropriate to locate free-roaming koalas in an area where they utilised a larger number of **Eucalyptus** species than the three found at Nowendoc. The restricted number of species at Nowendoc detracted from the suitability of that location to establish frequency of changes in species utilised. Though the Nowendoc animals appeared timid, it would be an acceptable risk in any replication of these observations, to capture all koalas seen for ear-tagging. The Nowendoc study indicated that if all the animals were captured within the first two months, hardly any new animals were likely to be encountered on subsequent visits. These few animals could then be captured for tagging as they were sighted. Tagging would greatly reduce the time required for identification, though the possibility that many koalas would leave the site remains as yet untested. The development of a radio transmitter which would have a suitable range and long period of transmission, without being too bulky for arboreal use by such strong and dextrous animals presents substantial difficulties. It would, however, facilitate the tagging procedure if the effects of tagging could be studied on a small number of animals using radio collars.

It may be possible to develop a procedure for quantitative analysis of tree use by koalas based upon examination of the readily identified faecal pellets. Their dispersion under the preferred trees might prove to be a suitable parameter, since it reduces the need for frequent human observer presence, with its attendant cryptic responses.

## 4.4 RECOMMENDATIONS FOR THE MAINTENANCE OF CAPTIVE KOALAS

There appeared to be substantial advantages in keeping captive koalas in enclosures containing only small numbers of individuals. This may reduce the stress produced, thus making feeding less fastidious. The animals may be more likely to breed. The enclosures ought also to show the animals well up above human observation level. It would be a more accurate exhibit for educational purposes.

The removal of the animals from human observation for periods may also prove beneficial. Since only a small number of koalas need be shown at any one time, others could be enclosed in a less stressed situation. This may reduce stress to a level where it is not necessary to provide such high quality browse so frequently, or to only exhibit zoo-bred koalas. One would expect that feeding difficulties might be reduced if fastidious feeding is linked to crowding and human presence. At present no firm data links fastidious feeding in koalas with crowding.

The provision of different housing for particular animals would allow the supply of preferred browse for those koalas which demonstrated idiosyncratic food preferences. This practice could minimise uneaten food and the need for such extensive and costly plantations of so many different **Eucalyptus** species. It would prevent the larger koalas consuming a disproportionate quantity of the browse when it is first offered, disadvantaging those animals having smaller stomachs.

There seems to be little purpose in pursuing the search for a single staple food species while koalas are enclosed in the present manner in Australian zoos and sanctuaries. The search for chemical leaf constituents has obscured non-chemical factors which appeared to be of greater importance.

It remains only to comment upon two questions about koala maintenance. These two questions have sometimes been erroneously compounded because of an unfortunate assumption that zoo conditions paralleled the free-roaming situation. The single question often asked was

"Why are koalas hard to keep?"

However the two separate issues are essentially
"Why are wild koalas difficult to introduce to captivity?" and
"Why are zoo koalas difficult to maintain?"

The answer to the first appeared to be that wild koalas were hard to introduce to captivity because of their cryptic response to human proximity, and because of the common practice of placing them in enclosures which were unsatisfactory because of their small size relative to the number of enclosed koalas. The solitary lifestyle of wild koalas had been overlooked and its significance not comprehended.

It is still not possible to account for the deaths of zoo koalas, such as the well-known Melbourne loss of 9 animals in 1935, or the Tidbinbilla loss of 15 in 1978.

## CHAPTER 4 SUMMARY

Concerning factors governing tree selection, most koalas remained on the site for many days once they had entered. Independent adult behaviour involved more local movement than that of the juveniles, or of females accompannied by juveniles. The less independent koalas tended to move only short distances overnight. Adults, though tolerant of juveniles, were themselves commonly spaced so that no two simultaneously occupied the same 50 $m.^2$ quadrat. No animal had exclusive use of any home range within the study site. Marginal trees were seldom used even though large **Eucalyptus** trees of all species occurred in these locations. The koalas placed very little stress upon the trees.

Hardly any trees could have been described as "eaten out", yet the koalas continued to move into new trees most nights. All year round the unit of entry and exit from the site was the individual koala. Climatic conditions apparently did not influence selection of trees or location of koalas within them.

Tree selection by koalas was conclusively demonstrated to be related to some factors which were not chemical features of the leaves. Overnight local movement was common among the independent adults.

The extent of use of "preferred" trees of any species by the wild koalas was shown to be minor. Some inter-species preferences were seasonal: others persisted year-round. The preference variations between individual koalas were sufficiently significant as to recommend that zoo animals be fed and enclosed only in small groups, if not separately.

A review of Clarke's "Prudent Folivore" model in the light of the field study suggested that considerations of stress due to the proximity of other adult koalas and of human observers may be more important than some chemical leaf constituents. The author considered the possibility that zoo animals may exhibit fastidious feeding in response to such stress, and that free-roaming animals are consequently less fastidious because they are less stressed.

Further observations in the wild were recommended, supported by the procedures developed in this study. Some changes in maintenance procedures for sanctuary koalas were recommended, based on this study.

# REFERENCES


Allen, D.L. (1943) Michigan fox squirrel management. **Lansing, Mich. Dept. Conservation, Game Div. Pub. 100:1-404**

Andrewartha, H.G. (1970) "Introduction to the Study of Animal Populations", (Chapman and Hall Ltd : London)

Anon. (1962) The Tucki scheme in the news again. **Wildl. Service 2(4):8-9**

Anon. (1977) New South Wales Koala Food Trees. Roneoed leaflet. (National Parks and Wildlife Service : Sydney)

Arnold (1977) 'Koalas'. (Macmillan : Melbourne)

Baker, R.T., and Smith, H.G. (1940) 'A Research on the Eucalypts, especially in Regard to their Essential Oils.' (New South Wales Government Printer : Sydney)

Barrett, C. (1943) 'Koala, the Story of Australia's Native Bear.' (Robertson and Muellens : Melbourne.)

Bergin, T.J., (Ed.), (1978) 'The Koala', Proc.Taronga Symp. (John Sands : Sydney.)

Berry, P.A., Macbeth, A.K., and Swanson, T.B. (1937) The carbonyl constituents of eucalyptus oils..Part II. the seasonal variation of **E. cinerifolia** oil. **J.Chem.Soc.(Lond.) 1937:1443-1447**

Betts, T.J., and Congreve, P. (1974) Initial observations on eucalyptus leaves eaten by koalas in Western Australia with especial reference to volatile oils. **Aust. J. Adv. Ed. 4(3):12-14**

Blair, W.F. (1940) Home ranges and populations of the meadow vole in southern Michigan. **J. Wildl. Manage. 4:149-161**

Blair, W.F. (1942) Size of home range and notes on the life history of the woodland deer-mouse and eastern chipmunk in northern Michigan. **J. Mammalogy 23:27-36**

Blair, W.F. (1953) Population dynamic of rodent and other small mammals. **Advance in Genet. 5:1-41**

Blakely, W.F. (1955) A Key to the Eucalypts. Second Edition.

Bolliger, A. (1953) The adrenals of the koala (**Phascolarctos cinereus** ) and their alleged relationship to eucalyptus diet. **Med. J. of Aust. 1:917-919**

Bracegirdle, M. (1978) 'Zoos are News.' (Abelard-Schuman : London)

Braysher, M. (1978) Introduction of Koalas into Tidbinbilla Nature Reserve. pp. 144-147 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp., (John Sands : Sydney)

Brown, L.E. (1962) Home ranges in small mammal communities. **Surv. Biol. Progr. 4:131-179**

Brownlee, G. (1940) **Quart J. Pharm. Pharmac. 13:130**

Burnett, N.M. (1938) The case for the koala. **Wildlife 1938:9-10**

Burt, W.H. (1940) Territorial behaviour and populations of some small mammals in southern Michigan. **J. Wildl. Manage. 4:149:161**

Burt, W.H. (1943) Territoriality and home range as applied to mammals. **J. Mammalogy 24:346-352**

Burt, W.H. (1946) "The Mammals of Michigan". (Univ. Michigan Press : Ann Arbor, Michigan)

Calhoun, J.B. (1956) Behaviour of house mice with reference to fixed points of orientation. **Ecology 37:287-301**

Clarke, J.S. (1980) The Significance of Koala Feeding Behaviour to Relocation Programmes. M.Sc. (Prelim.) thesis. University of New England.

Cleland, J.B. (1946) Cystinuria. Unpublished M.Sc. thesis. University of Adelaide.

Cockrum, E.L. (1962a) "Introduction to Mammalogy". (Ronald Press Co. : New York)

Cockrum, E.L. (1962b) "Laboratory and Field Manual for Introduction to Mammalogy". (Ronald Press Co. : New York)

Collins and Roberts, M. (1976) Arboreal Folivores in Captivity-Maintenance of a Delicate Minority. pp.5-12 in G.G.Montgomery, (Ed.), 'The Ecology of Arboreal Folivores', Proc.Nat.Zool.Park Symp.No.1 (Smithsonian Institute:Washington)

Congreve, P., and Betts, T.J. (1978) Eucalyptus Plantations and Preferences as Food for a Colony of Koalas in Western Australia. pp. 97-108 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands : Sydney)

Conn, E.E. (1978) Cyanogenesis, the Production of Hydrogen Cyanide by Plants. pp.301-310 in R.F.Keeler, K.R.Van kampen, and L.F.James, (Eds.), 'The Effects of Poisonous Plants on Livestock'. Proc.1977 U.S.-Aust.Symp.on Poisonous Plants. (Academic Press : New york)

Cork, S.J. (1979) Eucalypts as a dietary source for Australian marsupial folivores. Paper presented at 21st Annual Gen.Meeting Aust.Mammal Soc., Brisbane, May, 1979.

Cork, S.J., and Hume, I.D. (1978) Volatile fatty acid production rates in the caecum of the great glider. **Bull. Aust. Mammal. Soc. 5(1):24-25**

Cork, S.J., Warner, A.C.I., and Harrop, C.F.J. (1977) Preliminary study of the rate of passage of digesta through the gut of koala. **Bull. Aust. Mammal Soc. 4(1):24**

Crew, F.A. and Mirskaia, L. (1931) Effect of density on adult mouse populations. **Biologica Generalis 7:239-250**

Dalke, P.D. and Sime, P.R. (1938) Home and seasonal ranges of the eastern cottontail in Connecticut. **Trans. North Am. Wildl. Conf. Baltimore 3:659-669**

Danner, D.A. and Smith, N.S. (1980) Coyote home range, movement and relative abundance near a cattleyard. **J. Wildl. Manage. 44(2):484-487**

Davis D.E. (1953) Rat population. **Q. Rev. Biol. 28:373-401**

Davis, D.E. and Golley, F.B. (1963) "Principles in Mammalogy". (Reinhold Pub. Co. : New York)

Degabriele, R. (1973) Koalas thrive in a tropic haven. **Habitat 1(2):8-11**

Degabriele, R. (1977) The Environmental Biology of the Koala. M.Sc. thesis. University of New South Wales.

Dellow, D.W. (1978) Stomach structure and flow of digesta in macropod marsupials. **Bull.Aust.Mammal Soc. 5(1):25-26**

Dice, L.R. (1952) "Natural Communities" (Univ. Michigan Press : Ann Arbor, Michigan)

Dice, L.R. and Clarke, P.J. (1953) The statistical Concept of home range as applied to the recapture radius of the deer-mouse **(Peromysus). Contrib. Lab. Vertebrate Biol. Univ. Michigan 62:1-15**

Eberhard, I.H. (1972) Ecology of the Koala (**Phascolarctos cinereus**) (Goldfuss) on Flinders' Chase, Kangaroo Island. Doctoral thesis. University of Adelaide.

Eberhard, I.H. (1976) Ecology of the Koala (**Phascolarctos cinereus**) (Goldfuss) Marsupalia : Phascolarctidae in Australia. pp.315-327 in G.G.Montgomery, (Ed.), 'The Ecology of Arboreal Folivores', Proc.Nat.Zool.Park Symp.No.1 (Smithsonian Institute : Washington)

Eberhard, I.H., McNamara, J., Pearse, R.J., and Southwell, I.A. (1975) Ingestion and excretion of **Eucalyptus punctata** DC. and its essential oils by the koala (**Phascolarctos cinereus**) (Goldfuss). **Aust. J. Zool.** 23:169-179

Finnemore, H., Reichard, S.K., and Large, D.K. (1935) Cyanogenetic glucosides in Australian plants. **J.Proc.Royal Soc.N.S.W. 69:209-214**

Finnie, E.P.(1978) Autopsy Findings in Taronga Zoo Park. p.176 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands : Sydney)

Fleay, D. (1937) Observations of the koala in captivity. **The Aust. Zool. 9(1):68-80**

Foster, P.A. (1969) Koala (Food Trees). Roneoed leaflet. (National Parks and Wildlife service : Sydney)

Foster, P.A. (1975) Koala Food Trees. (National Parks and Wildlife Service : Sydney)

Freeland, W.J. and Janzen, D.H. (1974) Strategies in herbivory in mammals. The role of plant secondary compounds. **The Amer.Nat. 108:(961):269-289**

Gall, B. (1980) Aspects of the ecology of the koala **Phascolarctos cinereus** (Goldfuss) in Tucki Tucki Nature reserve, New South Wales. **Aust. Wildl. Res. 7:167-176**

Gall, B., and Rohan-Jones, W. (1977) Koala survey. **Parks and Wildl. 2(2):64-67**

Glander, K.E. (1976) Howling Monkey Feeding Behaviour and Plant Secondary Compounds: A Study of Strategies. pp. 561-574 in G.G.Montgomery (Ed.), 'The Ecology of Arboreal Folivores', Proc. Nat. Zool. Park Symp. (Smithsonian Institute: Washington)

Gunderson, H.L. (1976) "Mammalogy". (McGraw-Hill : New York)

Harrop, C.F.J., and Degabriele, R. (1976) Digestion and nitrogen metabolism in the koala **Phascolarctos cinereus. Aust. J. Zool. 24:201-215**

Harrop, C.F.J., and Degabriele, R. (1978) Food and Water Requirements of the Koala in Captivity. pp.45-61 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands : Sydney)

Hawkes, N.H. (1978) Identification and Management of Koala Eucalyptus Trees in New South Wales, pp.80-96 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands : Sydney)

Hayne, D.W. (1949) Calculation of size of home range . **J. Mammalogy 30:1-18**

Hayne, D.W. (1950) Apparent home range of **Microtus** in relation to distance between traps. **J. Mammalogy 31:26-39**

Heape, W. (1931) "Emigration, Migration and Nomadism". (W. Heffer and Sons Ltd. : Cambridge)

Hindel, M. (1979) Diet Selectivity in the Koala. B.Sc. (Hons.) thesis. Monash University, Melbourne.

Hinks, N.T., and Bolliger, A. (1957a) Gluconuria in a herbivorous marsupial, **Trichosurus vulpecula. Aust.J.Exp.Biol.Med.Sci. 35:37-44**

Howard, H.E. (1920) "Territory in Bird Life". (John Murray : London)

Huxley, J.S. (1934) A natural experiment on the territorial instinct. **Brit. Birds 27:270-277**

Iredale, T. , and Whitley, G. (1934) The early history of The koala. **Vict. Nat. 51:62-72**

Jackson, A.R.B. (1978) Some Notes on Diseases of Koalas in New South Wales, pp.155-157 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands : Sydney)

Jarman, P.J. and Taylor, R.J. (1983) Ranging of eastern grey kangaroos and wallaroos on a New England pastoral property. **Aust. Wildl. Res. 10:33-38**

Janzen, D.H. (1976) Complications in Interpreting the Chemical Defences of Trees against Tropical Arboreal Plant-eating Vertebrates, pp. 73-84 in G.G.Montgomery (Ed), 'The Ecology of Arboreal Folivores', Proc. Nat. Zool. Park Symp. No. 1 (Smithsonian Institute:Washington)

Jori, A., di Salle, E.A., and Pescador, R.J. (1972) **J. Pharm. Pharmac. 24:464-469**

Kershaw, J.A. (1934) The koalas on Wilson's Promontory. **Vict.Nat. 51:76-77**

Kershaw, K.A. (1964) "Quantitative and Dynamic Ecology", (Edward Arnold:London)

Kingsbury, J.M. (1964) 'Poisonous Plants of the United States and Canada'. (Prentice Hall:Englewood Cliffs)

Knight, C.B. (1965) "Basic Concepts of Ecology". (MacMillan and Co. : New York)

Ladiges, P.Y., and Ashton, D.Y. (1974) Variations in some central Victorian populations of **Eucalyptus viminalis** (Labill.) **Aust. J. Bot. 22:81**

Lay, D.W. (1942) Ecology of the opossum in eastern Texas. **J. Mammalogy 23:147-159**

Leeper, G.W. (Ed.) (1970) 'The Australian Environment', (CSIRO : Melbourne)

Lewis, F. (1954) The rehabilitation of the koala in Victoria. **Vict.Nat. 70(11):197-200**

Lyddaker, R. (1894) 'Handbook of Marsupalia and Monotremata.'

MacKenzie, W.C. (1918) 'The Gastro-intestinal Tract in Monotremes and Marsupials.' (Critchley-Parker : Melbourne)

MacKenzie, W.C. (1934) Comparative anatomy and the koala. **Vict.Nat. 51:58-61**

MacKenzie, W.C., and Owen, W.T. (1919) 'The Glandular System in Monotremes and Marsupials', (Jenkins, Buxton and Co. : Melbourne)

Manville, R.H. (1949) A study of small mammals in northern Michigan. **Misc. Publ. Museum Zool. Univ. Michigan 73:1-83**

McKern, H.G., Spies, M.C., and Willis, J.L. (1951) Critical Studies on Variations in Essential Oil Yields and Composition within and between Individual Trees of Various Eucalyptus Species. Paper presented ANZAAS Congress, Brisbane, 1951.

McKenzie, R.A. (1978) The caecum of the koala **Phascolarctos cinereus:** light, scanning and transmission electron microscopic observations on its epithelia and flora. **Aust.J.Zool. 26:249-256**

McNab, B. (1976) Energetics of Arboreal Folivores: Physiological Problems and Ecological Consequences of Feeding on a Ubiquitous Food Supply, pp.153-162 in G.G.Montgomery, (Ed.), 'The Ecology of Arboreal Folivores', Proc.Nat.Zool.Park Symp.No.1 (Smithsonian Institute : Washington)

McNally, J. (1960) Koala management in Victoria. **Aust. Mus. Mag. 13(6):178-181**

McRae, W.A., Landers, J.L. and Garner, J.A. (1981) Movement patterns and home range of the gopher tortoise. **Am. Midl. Nat. 106:165-179**

Mohr, C.O. (1947) Table of equivalent populations of north American small mammals. **Amer. Midl. Nat. 37:223-249**

Moore, S. (1979) Herb's preserving koalas . **Northern Daily Leader, January 8, 1979:2**

Morrison, P.R. (1962) Temperature Regulation in Animals Native to Tropical and High Altitude Environments, pp. 389-414 in J.P.Hannon and E.Veireck (Ed.) 'Comparative Physiology of Temperature Regulation', (Arctic Aeromedical Lab.: Fairbanks)

Morrison, R.G. (1981) 'A Field Guide to the Tracks and Traces of Australian Mammals' (Rigby: Melbourne)

Nagy, J.G., Steinhoff, H.W., and Ward, G.M. (1964) Effects of essential oils of sagebrush on deer rumen microbial function. **J.Wildl.Manage. 28:785-790**

Nice, M.M. (1941) The role of territory in bird life. **Am. Midl. Nat. 26:441-487**

Noble, G.K. (1939) The role of dominance in the social life of birds. **Auk 56:263-273**

Nolan, J. (1968) Eucalypts not koalas' only food. **Wildl. in Aust. 6:76**

Odum, E.P. (1959) "Fundamentals of Ecology". (W.B. Saunders Co. : Philadelphia)

Orloci, L. (1967) An agglomerative method for classification of plant communities. **J. Ecology 55:193-206**

Parra, R. (1976) Comparison of Foregut and Hindgut Fermentation in Herbivores, pp.205-209 in G.G.Montgomery, (Ed.), 'The Ecology of Arboreal Folivores', Proc.Nat.Zool.Park Symp.No.1 (Smithsonian Institute : Washington)

Parris, H.S. (1948) Koalas on the lower Goulburn. **Vict. Nat. 64(10):192-193**

Pearse, R.J., and Eberhard, I.H. (1978) Conservation of Koalas, pp.213-222 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands : Sydney)

Penfold, A.R., and Willis, J.L. (1961) 'The Eucalypts.' (Interscience Pub. : New York)

Philpott, C.M. (1965) The Ecology of the Koala (**Phascolarctos cinereus**) (Goldfuss), on Flinders' Chase, Kangaroo Island. B.Sc. (Hons.) thesis, University of Adelaide.

Pratt, A. (1937) 'The Call of the Koala'. (Robertson and Muellens:Melbourne)

Pryor, L.D. (1976) 'The Biology of Eucalypts.' (Edward Arnold : London)

Pryor, L.D., and Johnson, L.A.S. (1971) 'A Classification of Eucalypts', Second Edition.

Robbins, M., and Russell, E. (1978) Observations on Movements and Feeding activity of the Koala in a Semi-Natural Situation. pp. 29-41 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands:Sydney)

Robinson, A.C. (1978) The Koala in South Australia, pp. 132-143 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp., (John Sands:Sydney)

Robinson, P.T. (1978) Koala Management and Medicine in the San Diego Zoo, pp. 166-173 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp., (John Sands:Sydney)

Sanderson, G.C. (1966) The study of mammal movements - a review. **J. Wildl. Manage. 30:215-235**

Scoggins, B.A. (1978) Adrenal Steroid Production by the Koala, pp.198-199 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands : Sydney)

Serventy, V., and Serventy, C. (1975) 'The Koala.' (E.P.Dutton and Co. : New York)

Seton, E.T. (1909) "Life Histories of Northern Animals. An Account of the Mammals of Manitoba". (Charles Scribner's Sons : New York)

Shepherd, N.C. (1978) The Legal Status of the Koala in the Eastern States of Australia, pp.203-212 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands : Sydney)

Singer, F.J., Otto, D.K., Tipton, A.R. and Hable, C.P. (1981) Home ranges, movements and habitat use of european wild boar in Tennessee. **J. Wildl. Manage. 45(2):343-353**

Smith, F.V. (1971) 'Purpose in Animal Behaviour'. (Hutchinson University Library:London)

Smith, M. (1976a) The koalas of Lone Pine sanctuary- Part one. **Wildl. in Aust. 13:57-60**

Smith, M. (1976b) Koala- Part two. **Wildl. in Aust. 13:93-97**

Smith, M. (1979a) Notes on reproduction and growth in the koala **Phascolarctos cinereus** (Goldfuss). **Aust. Wildl. Res. 6:5-12**

Smith, M. (1979b) Behaviour of the koala, **Phascolarctos cinereus** Goldfuss in captivity. I. Non-social behaviour. **Aust. Wildl. Res. 6:117-129**

Smith, M. (1979c) Behaviour of the koala, **Phascolarctos cinereus** Goldfuss in captivity. II. Parental and infantile behaviour. **Aust. Wildl. Res. 6:131-140**

Snyder, R.L. (1976) "The Biology of Population Growth ". (Croom Helm Ltd : London)

Southwell, I.A. (1973) Variation in the leaf oil of **Eucalyptus punctata. Phytochem. 12:1341-1343**

Southwell, I.A. (1978) Essential Oil Content of Koala Food Trees, pp. 62-74 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands:Sydney)

Stickel, L.F. (1954) A comparison of certain methods of measuring ranges of small mammals. **J. Mammalogy 3:1-15**

Stokes, A. (Ed.) (1974) "Territory". (Dowden, Hutchinson and Ross, Inc. : Strousburg, Pa.)

Sutton, C.S. (1934) The koala's food trees. **Vict. Nat. 5(3):78-88**

Troughton, E. (1941) 'Furred Animals of Australia.' First Edition. (Angus and Robertson : Sydney)

Ward, J.H. (1963) Hierarchical grouping to optimize objective performance. **J. Amer. Stat. Ass. 58:236-244**

Warneke, R. (1978) The Status of the Koala in Victoria. pp. 109-114 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands:Sydney)

Watson, R. (1979) Koalas lose fertility in food crisis. **Rockhampton Sunday Sun, May 27, 1979:12**

Weiss, M., and Richards, P.G. (1970) Adrenal steroid secretion in the koala **Phascolarctos cinereus. J.Endocrin. 48:145-146**

Wicks, J.R. (1978) Koala Preservation in an Urban Situation. pp. 148-151 in T.J.Bergin, (Ed.), 'The Koala', Proc.Taronga Symp. (John Sands:Sydney)

Wilks, B.J. (1963) Some aspects of the ecology and population dynamics of the pocket gopher (**Geomys bursarius**) in southern Texas. **Texas J. Sci. 15:241-283**

Williamson, H.D. (1977) 'The Year of the Koala', (A.H. and A.W. Reed:Sydney)

Wishart, D. (1978) CLUSTAN* User Manual, Third Edition, Inter University Research Council Series, report No. 47, Edinburgh.

Veitch, C. (1980) The big koala round-up of French Island. **Aust. Womens Weekly, January 9, 1980:22-23**

APPENDIX A

THE SANCTUARY SURVEY QUESTIONNAIRE.

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KOALA FEEDING BEHAVIOUR

SANCTUARIES FEEDING PRACTICES SURVEY PILOT VERSION

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A.Logistics

LOCATION:

INFORMANT:

NUMBER OF ANIMALS: females males pouched juveniles

AREA:

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SURVEY PURPOSE:

In his preface to the 1976 Taronga Symposium on Koalas, Tom Bergin claimed:

" The koala's fastidious food preferences remain too complex to be understood with our present attitudes and techniques."

By reviewing present feeding practices in sanctuaries, I hope to establish how adequate contemporary understanding of koala nutrition is.

RATIONALE:

To research beyond the almost folklore concerning the alleged dietary whims of the koala,it is necessary to substantiate any proposition that the current understanding of dietary needs is demonstrably unsatisfactory.

One might do so if, as some have claimed, koalas in captivity differ from field animals with regard to the following parameters associated with nutritional inadequacies:

(i) Reduced Longevity.

(ii) Higher Mortality rates among Juveniles.

(iii) Inferior Breeding Frequencies.

(iv) Differential Weight Gain rates.

(v) Increased Disease Susceptibility.

This survey is an attempt to assess whether the frequency of such parameters in koala sanctuaries is indicative of major inadequacies in feeding practices. It is associated with field studies of animals in the South-East of Walcha.

B. Concerning Feeding Practices.

1. Number of animals free-browsing in established trees:

Number of animals caged and fed on collected browse:

2. In the free-browse situation, are the following trees available?

| | | Available? | Number? | Maturity? |
|---|---|---|---|---|
| **E. tereticornis** | Forest Red Gum | | | |
| **E. punctata** | Grey Gum | | | |
| **E. viminalis** | Manna Gum | | | |
| **E. microcorys** | Tallow Wood | | | |
| **E. camaldulensis** | River Red Gum | | | |
| **E. pauciflora** | White Sallee | | | |
| **E. pilularis** | Blackbutt | | | |
| **E. saligna** | Blue Gum | | | |
| **E. obliqua** | Messmate | | | |
| **E. robusta** | Swamp Mahogany | | | |
| **E. melliodora** | Yellow Box | | | |

Others?

3. Is the location a natural **Eucalyptus** stand or a plantation?

4. In view of the inconsistent feeding preferences recorded in the published literature,

a. Is there any obvious sustained preference for certain species in this sanctuaries' animals?

b. Is there any evidence of favoured trees within the same species?

c. In assessing koala usage, what parameters are used? defoliation? claw marks? roosting position? observed feeding?

d. Are favoured trees similar in form? Similar in age?

e. Do you consider koala feeding preferences might be motivated by behavioural preferences, rather than nutritional or olfaction considerations?

f. Are there observable seasonal changes in feeding behaviour, such as:

(i) Animals eat fewer species?

(ii) Some species not eaten in rain periods?

(iii) Changes in the proportion of juvenile and adult leaf chosen?

(iv) Do you restrict browsing animals from any species seasonally?

g. Can you instance unexplained changes in feeding behaviour or is most feeding behaviour predictable?

5. Regarding restricted animals, fed on collected browse,

a. Is the source of browse natural or plantation?

b. Which harvesting methods are used?

(i) Harvesting by coppice removal ( whole stem at stump)?

(ii) Lopping ( removal of branches at about 3 metres up )?

(iii) Pruning ( removal of crown branches )?

c. Frequency of offering food.

Fresh food is cut and offered daily?

Fresh food is offered daily from cuttings made less often?

Cut branches are placed in water?

d. Number of species offered?

e. Are any single **Eucalyptus** species capable of year-round support of the koalas?

f. Do you make seasonal changes in the food offered?

g. Do you control the proportion of juvenile, mature and epicormic leaf offered to restricted animals?

h. Do animals also eat bark, fruit, flowers, buds, earth?

i. Is it possible to quantitise the daily consumption of koalas in the sanctuary?

j. Does this consumption rate increase with lactation?

k. Have you any evidence of the alleged coprophagic feeding claimed by Minchin?

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C. Concerning Animal Behaviour.

Comment on the following statements:

6. Few animals may be approached during daylight without some indications of alertness.

7. Few animals feed significantly during the daylight period.

8. Most animals rest in trees different from those in which they regularly feed.

9. Feeding trees have common form.
   common age.
   similar leaf oil content.
   particular locations.
   similar trunk bark.

10. Rest trees have common form.
    common locations.
    similar trunk bark.

11. Is there any evidence concerning the suggestion that favoured browse trees may contain chemical substances needed regularly, if not daily?

12. Is there any evidence that such a substance might be more acutely required seasonally?

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D. Concerning Transferred Animals.

13. Means of recognising stress in captive animals?
    - Haematological data?
    - Weight loss?
    - Behaviour?
    - Other?

14. Means of reducing stress?
    - Individual enclosure?
    - Companion animals?
    - Variation in foods offered?
    - Controlled environment?
    - Other?

15. Procedures used for induction of new animals.

16. Comment on the adaptability of captured animals brought to the sanctuary.

    a. Need for same species of regular browse.

    b. Quantitative data on recent success of entry.

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E. Concerning Longevity.

17. Quantitative data available:

    a. Recorded longevity of animals born in the sanctuary.

    b. Estimated age of animals born outside the sanctuary.

    c. % of population which die annually.

    d. % mortality of juveniles below 1 year.

    e. % mortality in juveniles which die below 2 years, but not 1 year.

    f. Are there more winter deaths?

    g. % deaths obviously related to nutritional inadequacies or digestion.

h. Most common established causes of death.

j. % adults which breed regularly.

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F. Statements for Comment.

18. Poisoning by cyanide, as suggested in the 1930's by Fleay and Pratt, appears unlikely.

19. Regular testing for cyanogenic glucosides is carried out on suspect food.

20. The role of cineole in favoured browse is probably insignificant.

21. Palatability and essential oil content are probably unrelated.

22. The existence of a chemical substance critical to adrenal cortical hormone activity in favoured browe is unlikely.

23. Diarrhoea and other digestion difficulty in koalas, is seldom associated with serious and persistent deterioration in animal condition.

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G. Unstructured Comment.

24. Reduced longevity.

25. Mortality rate among juveniles.

26. Breeding frequency.

27. Weight gain rates.

28. Disease susceptibility.

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Many thanks for your assistance,
Jim Clarke. U.N.E. 1979

APPENDIX B
PHOTOGRAPHIC RECORD PLATES.

A). The Quiet Valley Area.
Showing the Succession of Open Paddocks
and **Eucalyptus** Woodlands.

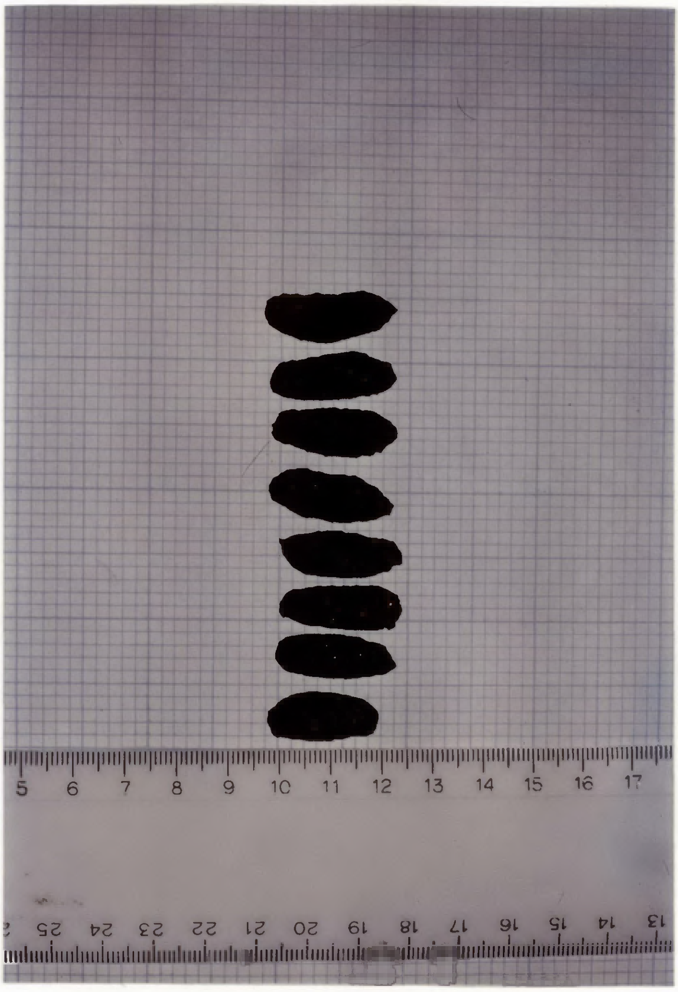
B). Typical Woodland Area Dominated by **Eucalyptus acaciiformis**

C). A Small **Eucalyptus stellulata**

D). **Eucalyptus pauciflora**

E). Watercourse with **Eucalyptus stellulata** Adjacent

F). Koala Faecal Pellets



G). A Tree Marker

H). Koala Claw Marks on a 1 m. Diameter Tree Trunk.

I). Telephoto Lens, Radio Transmitter and Dictaphone.

J). A Taronga Zoo Reference Animal Photograph.


K). Typical Field Study
Reference Animal Photograph
- Koala C35

L). Typical Field Study Reference Animal Photograph- Koala M92