THE ROLE OF ACACIA IN THE DIETS OF AUSTRALIAN MARSUPIALS – A REVIEW

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In Australia, Eucalyptus foliage is of major importance as a food source for the koala (Phascolarctos cinereus), common brushtail possum (Trichosurus vulpecula), common ringtail possum (Pseudocheirus peregrinus) and greater glider (Petauroides volans), and has received much attention in the literature over the last 20 years (Hume 1999). Other foliage sources are also eaten by marsupials, but these have received far less attention. One of these is Acacia. The genus Acacia is the most widespread and species-rich of all Australian plant genera, with about 600 species (Hall et al. 1972).

Acacia species are used by humans throughout the world (Boland 1989). In Australia, Acacia wood is used by Aborigines in the production of spears, clubs and boomerangs (Hall and Johnson 1993), and the resin of Acacia aneura (mulga) is used to hold spearheads to shafts and to mend broken tools and utensils. Parts of Acacia, particularly seeds, are used as food by Aborigines (Issacs 1987). The wood of Acacia is used for furniture and firewood (Pryor 1989; Vercoe 1989; Hall and Johnson 1993), the tannins from Acacia bark are used in tanning leather (Hall et al. 1972; Hall and Johnson 1993), and the pollen from several species, particularly A. baileyana (Cootamundra wattle) and A. doratoxylon is important for honey production (Hall et al. 1972). Acacia trees are planted as shelter belts (many species) and as ornamentals (e.g., A. baileyana). The golden flower-balls of A. pycnantha (golden wattle) have become the national floral emblem, and are found in the Australian coat of arms as well as in the insignia of the Order of Australia.

Acacia aneura (mulga) is widespread throughout the drier regions of Australia on a variety of soils. It is a low-quality browse that, when fed to stock, is considered a maintenance-only diet (Wheeler and Freer 1986; Norton 1994a,b,c). However, it is a valuable drought reserve for domestic sheep and cattle (Hall et al. 1972; Lynch and Alexander 1986; Wheeler and Freer 1986; Pritchard et al. 1992; Miller 1994). During drought, mulga foliage is cut and fed directly to stock, but in natural grazing situations animals have to rely on windfalls of leaves and...
seedpods that would otherwise be out of reach on high branches (Wheeler and Freer 1986; Gutteridge and Shelton 1994). The foliage and seed pods of *A. auriculiformis* have been fed to dairy cows in the Northern Territory (Vercoe 1989).

The use of *Acacia* foliage by Australian marsupials might seem limited, particularly when compared with the foliage of *Eucalyptus* species. However, not only the foliage of many *Acacia* species but also the gum, seeds, arils, pollen, nectar and sap of various species are eaten. The role of *Acacia* in the diets of Australian marsupials is the subject of this review.

**CHARACTERISTICS OF ACACIA**

The genus *Acacia* is in the Subfamily Mimosoideae of the Family Fabaceae or Leguminosae (Hall and Johnson 1993). Like all legumes, *Acacias* rely on symbiotic bacteria in their roots for the fixation of atmospheric nitrogen. Species of *Acacia* are found in most Australian environments including the arid zone, sea-coast, sub-alpine areas and rainforest (Pedley 1987; Hall and Johnson 1993). The 600 species of Australian *Acacia* range in height from 1 - 3 m shrubs as in *A. iteaphylla* (Flinders Ranges wattle) to trees of 8 - 15 m as in *A. excelsa* (ironwood) and *A. cambagei* (gidgee) and 20 - 30 m tall trees as in *A. bakeri* (Baker’s wattle) and *A. melanoxylon* (blackwood). Lifespans of *Acacia* species vary widely; *A. melanoxylon* can live for over 100 years, while *A. baileyana* deteriorates after 12 - 15 years (Hall et al. 1972; Hall and Johnson 1993). *Acacia* is often found as a pioneer species after fire or other disturbance, and is generally found in the understory of forests with a higher canopy of *Eucalyptus* species. In some instances it can be part of the upper canopy, depending on the environment and species (Hall et al. 1972).

Propagation of *Acacia* is primarily from seed (Adams and Attiwill 1984a,b) although some species like *A. harpophylla* and *A. argyrodendron* propagate via rhizomes (Pedley 1987). *Acacia* seeds may remain viable in the soil for at least 200 years before the seed coat is compromised. Fire is critical as a germination aid for *Acacia* seeds; without fire, germination can be delayed many years until the seed coat is compromised. Dispersal of *Acacia* seeds is mainly by mammals, birds and ants. O’Dowd and Gill (1986) divided Australian *Acacias* into three dispersal groups: 1) arillate *Acacia* dispersed by birds (17% of 92 species sampled); 2) arillate *Acacia* dispersed by ants (74%); and 3) non-arillate *Acacia* (9%) that are not dispersed by birds or ants. An aril is a fleshy appendage of the seed that is often brightly coloured or high in fat content to attract dispersal agents. Since most of the dispersal agents for *Acacia* are generalist feeders, for those which consume insects as a component of their diets mimicry must occur; the higher proportion of saturated fatty acids in the arils than in general plant tissues mimics the fatty acid composition typically found in animal prey (O’Dowd and Gill 1986).

*Acacia* has the ability to rapidly absorb nutrients, particularly nitrogen, and incorporate them into biomass after fire, enabling it to act as a pioneer species. This helps to prevent deterioration of the already low-quality soils from the eroding nature of the environment and also helps to conserve nutrients (Adams and Attiwill 1984a,b). Immediately after fire, *Acacia* species germinate and grow rapidly, and for a short time become the dominant shrub or tree species. At a study site 80 km east of Melbourne, *Acacia* species fixed more nitrogen in the soil (84% of the total above-ground nitrogen content), and produced greater biomass than *Eucalyptus* for three years after fire (Adams and Attiwill 1984a). Thereafter, *Eucalyptus* species began to overtake and overtop the *Acacia* and *Acacia* biomass and nitrogen content decreased. However, even with time, the wood from the *Acacia* was always higher in nitrogen than the wood of the *Eucalyptus*.

*Acacia* species are important in the regeneration of *Eucalyptus* forests, and there is concern about the loss of *Acacia* in *Eucalyptus* forests as a result of grazing by domestic stock and feral herbivores. Declines in abundance of *Acacia* species and in biomass have resulted in declines in those native animal species dependent on *Acacia* as a food source (Evans 1992). For example, rabbits (*Oryctolagus cuniculus*) have been thought to reduce or prevent full regeneration of *A. aneura*, *A. kempeana* and *A. papyrocarpa* in southern and central Australia (Barker 1987).

**USE OF ACACIA BY LIVESTOCK**

Because of the ability of *Acacia* to fix nitrogen, its nutritive value might be expected to be higher than that of non-leguminous browse species (Gutteridge and Shelton 1994). Instead, Australian *Acacia* tends to be lower in nutritive value, primarily due to the phylloide leaf structure and high tannin content of many species (Gutteridge and Shelton 1994; Norton 1994c). *Acacia* species have either bipinnate (or compound pinnate) leaves (these species are often called ‘wattles’) or phylloides (flattened petioles resembling leaves). The phylloide structure tends to be higher in fibre and thus lower in digestibility than pinnate leaves (Gutteridge and Shelton 1994).

Vercoe (1989) analysed the foliage of 29 *Acacia* species found in south-eastern Queensland, though only nine were observed to be browsed by domestic
A. argrodendron

Norton (1994a) summarised the composition of several Acacia species commonly consumed by domestic stock in Australia. Table 1, summarised in Table 1, show a wide range of nutrient content among Acacia species.

Although these nutrient contents indicate a high potential for using the foliage of some Acacia species as a feedstuff, other constituents also need to be considered. Acacia foliage and seed pods rarely have toxic effects on animals, but some contain secondary metabolites that may be feeding deterrents. Plant secondary metabolites act as deterrents to insect and fungal and bacterial attack. Secondary metabolites found in Acacia species include tannins - both condensed and hydrolysable, oxalates, cyanogens including cyanoagenic glycosides, and fluoroacetate. These secondary metabolites are found in the foliage, bark, seeds and even seed pods (Hall et al. 1972; Norton 1994c).

When ruminants consume high levels of tannins, the tannins form complexes with dietary proteins in the rumen, protecting the protein from microbial attack but also lowering protein availability to the animal (Gartner and Hurwood 1976; Norton 1994 a,c; Van Soest 1994). Tannins found in mulga are thought to contribute to low protein digestibility (Pritchard et al. 1992). It has been estimated that a forage containing 8% crude protein will provide sufficient ruminal ammonia for resident microbes (Norton 1994 a). Thus the crude protein levels found in Acacia (10.7 - 22.5%) would appear sufficient for domestic ruminants, but because of sometimes high tannin levels, available protein levels in most Australian Acacia species may not be adequate for sheep and cattle (Norton 1994a). Similarly, the majority of sulphur (found as S-containing amino acids) in mulga is probably of limited availability because of the high tannin content (Miller 1994). Nevertheless, even with these limitations, ruminants can survive on mulga for substantial periods if supplemented with small amounts of bone meal or meat and bone meal (as a phosphorus source), salt and molasses (Hall et al. 1972; Miller 1994). The molasses contributes energy and sulphur, balancing deficiencies found in mulga (Miller 1994).

**USE OF ACACIA BY MARSUPIALS**

Table 2 lists all Australian marsupials known to use some part or product of the Acacia plant as a food source.

**Acacia foliage**

As indicated earlier, Acacia foliage is only used as a feedstuff for domestic livestock in times of drought or food shortage. Likewise, the majority of macropods do not consume Acacia foliage until forced to under drought or low-food supply situations. Some species such as the euro (Macropus robustus erubescens) will not consume Acacia even then (Allen 2001). This may be due in part to the low nutritive value of Acacia foliage because of high tannin levels. Fresh Acacia foliage is usually not within physical reach of macropods and most Acacia foliage that is consumed is taken as dry leaf litter. This dry litter is a critical food resource for yellow-footed rock-wallabies (Petrogale xanthopus) in the Grey Range of Queensland (Allen 2001). Norton (1994c) indicated that when Acacia leaves are dried, tannin concentrations are substantially decreased. Thus leaf litter from Acacia foliage loses some of its ‘anti-feedant’ properties. Nevertheless, some marsupials have been recorded feeding on fresh Acacia foliage.

### Table 1. Nutrient content (dry matter basis) of Acacia species commonly consumed by domestic stock in Australia.

<table>
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<tr>
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<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>10.9 - 18.3</td>
<td>14.7</td>
<td>10.7 - 22.5</td>
</tr>
<tr>
<td>Phosphorus, %</td>
<td>0.06 - 0.18</td>
<td>0.11</td>
<td>0.04 - 0.23</td>
</tr>
<tr>
<td>Potassium, %</td>
<td>0.39 - 1.55</td>
<td>0.78</td>
<td>0.79 - 1.25</td>
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<tr>
<td>Sodium, %</td>
<td>0.01 - 0.81</td>
<td>0.22</td>
<td>0.38</td>
</tr>
<tr>
<td>Calcium, %</td>
<td>0.5 - 3.4</td>
<td>1.4</td>
<td>0.92 - 2.60</td>
</tr>
<tr>
<td>Magnesium, %</td>
<td>0.18 - 0.66</td>
<td>0.35</td>
<td>0.19</td>
</tr>
<tr>
<td>Ca/P</td>
<td>4.1 - 42.5</td>
<td>14.2</td>
<td>-</td>
</tr>
<tr>
<td>Cu, ppm</td>
<td>0.6 - 10</td>
<td>3.9</td>
<td>-</td>
</tr>
<tr>
<td>Zn, ppm</td>
<td>25 - 54</td>
<td>35</td>
<td>-</td>
</tr>
<tr>
<td>Mn, ppm</td>
<td>29 - 206</td>
<td>132</td>
<td>-</td>
</tr>
<tr>
<td>Apparent digestibility of dry matter in vivo (%)</td>
<td>30.8 - 38.4</td>
<td>38.4</td>
<td>39.2 - 52.7</td>
</tr>
</tbody>
</table>
Table 2. Australian marsupials that commonly use Acacia gum, foliage, arils, seeds and pollen/nectar as a dietary component.

<table>
<thead>
<tr>
<th>Species</th>
<th>Gum</th>
<th>Foliage</th>
<th>Arils</th>
<th>Seeds</th>
<th>Pollen/Nectar</th>
</tr>
</thead>
<tbody>
<tr>
<td>sugar glider Petaurus breviceps</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>mahogany glider P. gracilis</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>squirrel glider P. norfolcensis</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yellow-bellied glider P. australis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leadbeater’s possum Gymnobelidius leadbeateri</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>common brushtail possum Trichosurus vulpecula</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mountain brushtail possum T. cunninghami</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>common ringtail possum Pseudocheirus peregrinus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>common spotted cuscus Spilocuscus maculatus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rufous rat-kangaroo Aepyprymnus rufescens</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tasmanian bettong Bettongia gaimardi</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>brush-tailed bettong B. pencillata</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rufous hare-wallaby Lagorchestes hirsutus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>red kangaroo Macropus rufus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>grey kangaroos M. giganteus, M. fuliginosus</td>
<td>X</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>black-striped wallaby M. dorsalis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tammar wallaby M. eugenii</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>brush-tailed rock-wallaby Petrogale penicillata</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>yellow-footed rock-wallaby P. xanthopus</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>swamp wallaby Wallabia bicolor</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>southern brown bandicoot Isoodon obesulus</td>
<td>X</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Common brushtail possum Trichosurus vulpecula

This species has an extensive range throughout Australia and, because of that range, its dietary components vary widely (Kerle 1984). T. vulpecula is a folivore/ frugivore (Hume 1999), with leaves from a variety of plant species, including Eucalyptus and Acacia, being important components of its diet. Much of the foliage, fruit, flowers and fungi favoured by T. vulpecula is toxic to other animals, thus it must have the ability to detoxify some of the plant secondary metabolites it consumes.

Trichosurus vulpecula are thought to select Acacia leaves based on nutrient and fibre content. T. vulpecula has a smaller relative gut capacity than P. volans and Ps. peregrinus, both of which are more highly specialised eucalypt folivores (Crowe and Hume 1997). Thus enzymatic digestion in the small intestine is relatively more important, and microbial fermentation in the hindgut of T. vulpecula is less so, hence the strong selection against dietary fibre.

Statham (1984) found that T. vulpecula living in a plantation of pine trees (Pinus radiata) in four Tasmanian forests consumed 25% of their diet as A. dealbata foliage. Fitzgerald (1984) studied T. vulpecula in an area of dry sclerophyll forest in Tasmania where A. dealbata and A. melanoxylon were the most common understorey species. At this site, the diet of T. vulpecula was primarily grasses and herbs supplemented with Acacia and Eucalyptus leaves. Acacia and Eucalyptus pollen and leaf petioles were identified in faecal pellets throughout the year. Foliage from the Acacia species (mostly A. dealbata) was consumed throughout the year but it increased in importance in autumn and winter.

Evans (1992) evaluated the diet of T. vulpecula in three areas of central Australia. The leaves of A. coriacea were preferred dietary constituents, together with the foliage from three other Acacia species; A. aneura, A. esteophiolata and A. tetragonophylla. Epidermal fragments of Acacia leaves in faecal pellets of T. vulpecula indicated that leaves and flowers of three of the four Acacia species were selected, but for A. tetragonophylla only the leaves were consumed. Flowers ingested at all sites were almost exclusively of Acacia species, with the amount of flowers often exceeding the amount of leaves. The decline in T. vulpecula numbers in central Australia has been linked to the grazing of favoured Acacia species by domestic livestock, resulting in decreased availability of favoured foliage (Evans 1992).

Mountain brushtail possum Trichosurus cunninghami

The mountain brushtail possum, or bobuck, is a herbivore/frugivore found in wet forests from southeastern New South Wales (NSW) to southern Victoria (Lindemayer et al. 2002). Its dietary components are primarily Acacia leaves, fungi, fruit, buds, lichens and occasionally bark (Seebeck et al. 1984). This animal is a hindgut fermenter with a
gastrointestinal tract that resembles that of *T. vulpecula* (Hume 1999).

Seebeck et al. (1984) studied the ecology of *T. cunninghami* living in a forest dominated by *Eucalyptus regnans* in the Central Highlands of Victoria. The open tall understorey (c. 15 - 20 m) was predominantly *A. dealbata* (with some *A. frigescens* and *A. obliquinervia*), and *A. anserinifolia* as a ground layer (< 0.5 m). The most common constituent of *T. cunninghami*’s diet at this study site was *Acacia* leaves, mostly *A. dealbata*. *A. dealbata* was the preferred food in 10 of 14 months for a mean of 92% of the *T. cunninghami* population. *A. anserinifolia* was consumed frequently, particularly in winter and spring. *A. frigescens* was also consumed year round, with higher percentages during summer and autumn. Fungi were consumed by 44% of the population as the second most preferred food after *Acacia* leaves. A similar range of dietary items was found by Wright (2000) in northeastern Victoria. Over 65% of identifiable fragments in the faeces were of *A. dealbata* leaf. Fungi (both epigal and hypogal) made up approximately 20%, leaves of other (unidentified) plants made up 15%, and mistletoe the remainder.

**Common ringtail possum Pseudocheirus peregrinus**

*Pseudocheirus peregrinus* is a hindgut fermenter with a large caecum. It practises caecotrophy, which is thought responsible for its lower maintenance nitrogen requirement (Chilcott and Hume 1985) than non-coprophagic folivores such as *T. vulpecula* and *T. cunningharni*.

Pahl (1984) found that *Ps. peregrinus* in Victoria ate predominately *Eucalyptus* foliage, occasionally supplemented with foliage from *A. melanoxylon*. Cork and Pahl (1984) reported that *Ps. peregrinus* selected foliage for maximal nitrogen intake and minimal cell wall (fibre) content. The mature foliage of *A. melanoxylon* has 2.3% total nitrogen and 61% total cell-wall content, compared with values of 3.3% and 46% found in immature foliage (Table 3). Young foliage was consumed more frequently than mature foliage, even though younger leaves often had higher tannin levels. However, the nutrient content of foliage could not be correlated with either the ringtail’s preferences for particular tree species or for either young or mature foliage. *A. melanoxylon* was higher in nitrogen, lower in tannins and had a similar lignin concentration to *Eucalyptus ovata*, but was not selected in preference over *E. ovata*. It is thought that toxic plant secondary metabolites influenced foliage choice.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Immature</th>
<th>Mature</th>
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<tbody>
<tr>
<td>Total nitrogen</td>
<td>3.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Total phenolics</td>
<td>16.2</td>
<td>16.4</td>
</tr>
<tr>
<td>Total tannin</td>
<td>4.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Condensed tannins</td>
<td>4.9</td>
<td>4.6</td>
</tr>
<tr>
<td>Relative astringency</td>
<td>6.2</td>
<td>7.2</td>
</tr>
<tr>
<td>Total cell-walls</td>
<td>45.7</td>
<td>60.9</td>
</tr>
<tr>
<td>Cellulose</td>
<td>19.6</td>
<td>17.4</td>
</tr>
<tr>
<td>Lignin</td>
<td>17.3</td>
<td>26.8</td>
</tr>
</tbody>
</table>

**Table 3. Nutrient content (percent of dry matter) of immature and mature foliage of *A. melanoxylon* (Cork and Pahl 1984)**

**Common spotted cuscus Spilocuscus maculatus**

*Spilocuscus maculatus* is found in the rainforests of Cape York Peninsula, and in the fringes of freshwater and marine mangroves (Winter and Leung 1995). It consumes a variety of rainforest fruits, and also flowers and leaves from rainforest plants such as buttonwood (*Glochidion* species). However, in captivity, it was found to prefer the young leaves of several *Acacia* species and wild mango (*Mangifera indica*).

**Kangaroos and wallabies**

The macropods (kangaroos and wallabies) are foregut fermenters; the gastrointestinal tract and its function are described by Hume (1999). These animals host a symbiotic microbial population that aids in fibre digestion in an expanded forestomach. Stevens and Hume (1995) indicated that the forestomach in macropods has more similarities to the equine colon than the rumen. The macropod’s small and large intestines are relatively short when compared to those of other herbivores. The large intestine or hindgut consists of a simple caecum and colon. Secondary microbial fermentation occurs in the caecum and the proximal colon (Hume 1999).

The larger kangaroos - *Macropus rufus* (red kangaroo), *M. giganteus* (eastern grey kangaroo) and *M. fuliginosus* (western grey kangaroo) - do not usually consume foliage of *Acacia* species. However, in times of drought, when other foodstuffs have been consumed, certain *Acacia* species may be consumed as a survival mechanism. For instance, Dawson et al. (1975) found that during summer in the arid zone of western NSW, *Acacia* was not consumed by *M. rufus* or *M. r. erubescens*, but was consumed by feral goats (*Capra hircus*). However, Barker (1987) observed *M. rufus* and *M. fuliginosus* eating *A. victoriae* (prickly wattle), and also *Cassia* species, another legume, during a drought in Kinchega National Park in 1981 when pasture biomass fell below 100 kg/ha.
Like the larger kangaroos, the black-striped wallaby (Macropus dorsalis) is also classified as a grazer (Hume 1999), but it is always found closely associated with specific vegetation types, such as brigalow (A. harpophylla) woodland, rainforest, or dense wet sclerophyll forest, usually with vines and creepers (Jarman et al. 1991). Three sites were evaluated by Jarman et al. (1991), two in brigalow and one in a wet sclerophyll forest. Faecal pellets of the animals in the brigalow woodland contained small amounts of A. harpophylla. It is assumed that the animals consumed the Acacia opportunistically, and that it was not a foliage commonly selected. Nevertheless, in dry seasons the amount of browse in the diet of this species can increase up to 16% (Ellis et al. 1992).

Rock-wallabies (Petrogale sp.) tend to be intermediate browser-grazers (Sanson 1978). Two species are reported to consume Acacia foliage as a significant dietary component. Along the Goulburn River north of Sydney, the diet of the brush-tailed rock-wallaby (P. pennicillata) included 35 - 50% grass, 25 - 40% forbs and 12 - 30% browse (Short 1989). The vegetation consisted of an open scrub of A. doratoxylon and Eucalyptus species, along with A. linearifolia lining a dry creek bed. Collected faecal pellets indicated that the major browse selected was A. doratoxylon. The yellow-footed rock-wallaby (P. xanthopus) is a vulnerable species whose range is now limited to arid and semi-arid areas of South Australia, NSW and Queensland. Its diet varies with season and rainfall, but is primarily forbs, chenopods, grass and browse (Dawson and Ellis 1979; Copley and Robinson 1983). When there is abundant rainfall, forbs and grasses are the primary constituents. In drought, the animals consume the leaves of woody shrubs and trees, including dry leaf litter that is composed mainly of Acacia spp. (Allen 2001).

The swamp wallaby (Wallabia bicolor) is found in dense forest and woodlands along eastern Australia from Cape York Peninsula to south-western Victoria. It is classified as a browser (Sanson 1978), and dietary components include a wide range of browse such as shrubs, bushes and pine tree seedlings, as well as agricultural plants from fields adjacent to its habitat. The diets of W. bicolor from two sites in north-eastern NSW were compared by Hollis et al. (1986). At one site, animals consumed A. melanoxylon foliage at an annual average of 5.3% of total food intake, mainly in winter and spring. At the other site, the annual average consumption of A. melanoxylon was 2.3%, primarily in autumn. A female joey kept in a captive environment consumed A. armata foliage readily and did well (Edwards and Ealey 1975). Thus W. bicolor is an opportunist that consumes a wide range of browse, including Acacia.

**Acacia gum**

Smith (1982a) was the first to report on the importance of gum feeding by Australian mammals. Gums are one of the plant exudates most commonly consumed by some omnivorous marsupials, with other exudates including nectar, sap, manna, kie and resins (Hume 1999). Acacia gums are classified as glycans or complex polysaccharides of plant origin, or hydrocolloids that dissolve and form a gel in water (Adrian 1976). Gum arabic is used commercially throughout the world and is produced from the African species Acacia senegal. Several Australian Acacia species also produce gum with qualities close to those of gum arabic (Hall et al. 1972), although they are less water soluble (Smith 1982a; Hume 1999), are slightly redder in colour and contain analysable levels of tannin (Mantell 1949).

Gums from Australian Acacias are secreted from sites of mechanical or insect damage as the plant attempts to seal off the injured site and so prevent loss of water and invasion by pathogenic bacteria and viruses (Smith 1982a). During dry, hot weather, gum nodules form on branches of Acacia (Lindenmayer 1996) and are readily consumed by gliders and possums. These animals also incise or create artificial openings on the trunk and upper branches of specific Acacia trees in order to harvest gum. Many factors affect the amount of gum produced by an Acacia, such as season, species and tree size (Smith 1982a; Lindenmayer et al. 1994).

Generally, only mature Acacias produce gum in significant amounts. Lindenmayer et al. (1994) found a range of 24% to 68% sugars among several Acacia species. Animals harvesting Acacia gum are likewise highly selective for the type of Acacia tree. Table 4 lists Acacia species that are regularly harvested for gum by Australian gummivores. Total nitrogen in Acacia gum is low (0.2 to 0.7%) (Lindenmayer et al. 1994). The varying amounts of sugar and nitrogen found in Acacia gum may well play a role in determining the number of gummivorous animals in any given area (Hume 1999).

Six intermediate-sized (70 - 700 g) omnivorous possums and gliders, described below, include some form of exudates in their diet. These may be derived from plants (gum, sap, nectar, manna) or insects (psyllid honeydew) and are a primary energy source. Arthropods (tree crickets, beetles, moths, spiders) and perhaps pollen serve as protein sources. This additional protein is essential as exudates are uniformly low in protein.

In order to use Acacia gum as an energy source, it is assumed that mammals must have the necessary gut flora capable of producing enzymes to ferment
the complex polysaccharides found in gum (Smith 1982a). These microflora are retained in enlarged fermentation chambers in the gastro-intestinal tracts of these marsupials, specifically the caecum (Hume 1999). An enlarged area of the gut at neutral pH is essential for microbial fermentation, and there is a direct relationship between the size of the hindgut caecum and the proportion of Acacia gum in the diets of these possums and gliders. The largest caecum is found in sugar gliders (Petaurus breviceps) (Hume 1999) and Leadbeater’s possums (Gymnobelideus leadbeateri) (Smith 1984a); Acacia gum is a major component of the diets of both of these animals. The mahogany glider (Petaurus gracilis) and squirrel glider (Petaurus norfolcensis) consume less gum and have smaller caecal capacity. The yellow-bellied glider (Petaurus australis) rarely consumes Acacia gum (Henry and Craig 1984; Goldingay 1986), and has an even smaller caecal capacity (Hume 1999). The striped possum (Dactylopsila trivirgata) consumes no Acacia gum and has the smallest caecal capacity of all the omnivorous possums and gliders. In fact, Smith (1982b) described Dactylopsila as an insectivore, but more information on its natural diet is needed before any definitive conclusion can be drawn. Likewise, quantitative data are needed on the likely contribution made by microbial fermentation of Acacia gums to the energy budget of the various species discussed above. The few mammals other than omnivorous possums and gliders known to consume Acacia gum include several African primates such as the yellow baboon (Papio cynocephalus) (Hausfater and Bearce 1976) and the lesser bushbaby (Galago moholi) (Bearder and Martin 1980). Like most of the omnivorous possums and gliders, both primates are hindgut fermenters, and G. moholi has a caecum which is proportionately as large as that of P. breviceps (Caton et al. 2000).

**Table 4. Acacia species known to produce gum acceptable to omnivorous possums and gliders in Australia.** 1, Sharpe and Goldingay 1998; 2, Strahan 1995; 3, Van Dyck 1993; 4, Lindenmayer 1996; 5, Menkorst and Collier 1987; 6, Smith 1984b; 7, Menkorst et al. 1988; 8, Smith 1984a; 9, Smith 1982a; 10, Kavangh 1987; 11, Henry and Suckling 1984; 12, Suckling 1984; 13, Howard 1989. *A. concurrens* is known as a source of seeds and arils, but may also be a gum resource.

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. concurrens</td>
<td>curracabah</td>
<td>1</td>
</tr>
<tr>
<td>A. crassicaarpa</td>
<td></td>
<td>2, 3</td>
</tr>
<tr>
<td>A. dealbata</td>
<td>silver wattle</td>
<td>2, 4, 5, 6, 7, 8</td>
</tr>
<tr>
<td>A. flavescens</td>
<td></td>
<td>2, 3</td>
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<td>A. frigescens</td>
<td>forest wattle</td>
<td>4</td>
</tr>
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<td>A. irrata</td>
<td>green wattle</td>
<td>1</td>
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<tr>
<td>A. mangium</td>
<td></td>
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<tr>
<td>A. mearnsii</td>
<td>black wattle</td>
<td>9, 10, 11, 12</td>
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<tr>
<td>A. obliguinervia</td>
<td>mountain hickory wattle</td>
<td>2, 4, 6, 8</td>
</tr>
<tr>
<td>A. pyemanta</td>
<td>golden wattle</td>
<td>2</td>
</tr>
<tr>
<td>A. terminalis</td>
<td>sunshine or cedar wattle</td>
<td>9, 13</td>
</tr>
</tbody>
</table>

**Sugar glider Petaurus breviceps**

The diet of Pet. breviceps is seasonally variable, consisting of Acacia gum, nectar and pollen, sap of some Eucalyptus and invertebrates. The use of Acacia gum by Pet. breviceps is well documented (Smith 1982a; Suckling 1984; Henry and Suckling 1984; Howard 1989; Quin 1995).

*Petaurus breviceps* in South Gippsland, Victoria studied by Smith (1982a) were in strips of roadside vegetation with a Eucalyptus canopy and a regenerating Eucalyptus and Acacia understorey. Pet. breviceps living in these strips fed predominantly on plant exudates, including gum of *A. mearnsii*, and Eucalyptus sap and nectar. An average of 43% of foraging time was spent feeding on *Acacia* gum. The animals moved along stems and branches, licking briefly at insect borer holes from which gum was exuding or had accumulated. In winter, the animals pried open the borer holes to gain access to the pocketed gum. They also ingested small particles of bark when feeding, especially in winter when they chewed holes in the bark to access the *Acacia* gum. Smith (1982a) concluded that the size of the *P. breviceps* population in his study area was regulated by the abundance of plant exudates, especially from *A. mearnsii*, in winter.

Smith (1982a) used the amount of bark in the faeces as an indicator of gum utilisation by the gliders - the percentage of bark in the faeces varying with season. Howard (1989) also used bark fragments in the faeces as an indicator of *Acacia* gum feeding, and observed that *A. terminalis* gum was harvested by *P. breviceps* throughout the year at his study site at Jervis Bay, NSW. However, gum was collected primarily in autumn (April), accounting for 42% of feeding observations, the value falling to 23% in spring (September), 10% in November, and...
Smith (1984a) reported that as honeydew (Smith 1984a; Lindenmayer 1997). Eucalyptus trees would be enough to provide a single Pet. breviceps with its annual energy requirements. Although insects and honeydew were more important than gum in late spring and early summer, while E. bridgesiana sap was harvested in late summer and early autumn, Smith (1982a) concluded that Pet. breviceps population densities could most readily be explained by the number of available A. mearnsii, and that home range size appeared to be inversely related to the abundance of A. mearnsii.

Quin (1995) reported that Pet. breviceps and Pet. norfolcensis on the north central coast of NSW relied on Acacia gum as well as Eucalyptus sap, manna, nectar and honeydew. Pet. breviceps fed primarily on Acacia gum in autumn and winter. The gum consumed in winter was mostly in the form of nodules from gum secreted in the summer. Leadbeater’s possum Gymnobeludius leadbeateri

The diet of Gym. leadbeateri consists primarily of arthropods together with plant exudates (Acacia gum, Eucalyptus manna), as well as insect exudates such as honeydew (Smith 1984a; Lindenmayer 1997). Smith (1984a) reported that Acacia gum is particularly important to Gym. leadbeateri in winter when other food sources are limited. This factor, together with the availability of tree hollows for nesting, probably accounts for the distribution of Gym. leadbeateri. The species of Acacia is important, as the animals consume gum from only three: A. dealbata, A. obliquinervia, and A. frigicrens.

As with most gumnivores, Gym. leadbeateri incise trees with their sharp teeth for gum collection. The practice of ‘wounding’ the bark of Acacia trees, together with the presence of bark in the faeces, is used as an indicator of gum consumption by the possum. Gum is completely digested by the animal’s digestive system and cannot be recovered in the faeces. The incised wound initiates the release of gum from the underlying cambium layer. The possums make repeated nocturnal visits to harvest gum seeping from these sites. It has been noted that the animals return to their nests in between feeding bouts to conserve energy, as the nodules of gum accumulate only slowly from wound sites (Smith 1984a; Lindenmayer 1996). Peak consumption of Acacia gum occurred in autumn (77% of total diet in March to May), with a depression in spring (29% in September to November). There was no difference in consumption between summer (54% in December to February) and winter (50% in June to August) (Smith 1984b). Gum consumption patterns did not follow patterns of gum availability, which peaks in late summer and decreases to zero in early spring. Smith (1984a) surmised that the higher gum consumption in autumn, based on high bark intake, reflected greater foraging effort for the Acacia gum in that season.

In another study, the diet and behaviour of Gym. leadbeateri were compared in three areas (Smith 1984b). Results from this and other studies indicated that the density of Gym. leadbeateri is determined by several factors: 1) availability of nest trees; 2) food resources, primarily gum from A. obliquinervia and A. dealbata; 3) foraging substrate suitability; and 4) competing species, especially Pet. breviceps. The animals at all three sites ate primarily Eucalyptus manna, Acacia gum, insect honeydew and arthropods. Acacia gums were most available from late summer to early winter (Smith 1984b).

Squirrel glider Petaurus norfolcensis

Petaurus norfolcensis has a more limited range in eastern Australia than does Pet. breviceps, but the constituents of the Pet. norfolcensis diet closely match that of Pet. breviceps, and include Acacia gum, sap of certain Eucalyptus species, arthropods, nectar and pollen (Quin 1995). Sharpe and Goldingay (1998) found that two Acacia species, A. irrorata and A. australocarpa, were harvested for gum in the autumn by Pet. norfolcensis on the north coast of NSW. However, since there were few large mature trees available in the area, all accumulated gum had been consumed before winter. Menkhorst et al. (1988) concluded that the gum of mature A. dealbata probably provided an important winter carbohydrate source for the squirrel glider in riparian open forests in north-eastern Victoria.

Yellow-bellied glider Petaurus australis

The diet of Pet. australis consists principally of Eucalyptus nectar and sap (Goldingay 1990). Quin (1996) concluded that this glider is a pollinator because of its activity and the variety of tree species visited, which included species not only of Eucalyptus but also Acacia, Casuarina, Podocarpus and Banksia. Based on the observations of several researchers (Henry and Craig 1984; Goldingay 1986), Pet. australis does not consume gum, and lacks the enlarged caecum thought essential for microbial fermentation of Acacia gum (Hume 1999). Kavanagh (1987), however, did record a sighting of a Pet. australis consuming gum from A. mearnsii (1.1% of all observations made).

Mahogany glider Petaurus gracilis

The endangered Pet. gracilis in coastal north Queensland is a dietary opportunist, feeding on
nectar, pollen, arthropods, *Acacia* exudate, lerp and honeydew. Nectar and pollen are clearly the most important food items (Jackson 2001). *Pet. gracilis* consumes gum from three *Acacia* species, *A. crassicarpa, A. flavescens* and *A. mangium*, but it is not a major food item.

**Rat-kangaroos *Bettongia* sp.**

Two potoroid marsupials that occasionally utilize gum from *Acacia* species are *Bettongia gaimardi* (Tasmanian bettong) and *B. pencillata* (brush-tailed bettong) (Hume 1999). Primary dietary components of both bettongs include hypogeous fungi, but faecal samples provide evidence that the animals also occasionally consume gum of *A. mearnsii* or *A. dealbata* in spring and summer. Rose and Johnson (1995) cited observations of *B. gaimardi* with a gummy substance in the stomach that was thought to be *Acacia* gum. Taylor (1992) directly observed a *B. gaimardi* consuming gum from *A. dealbata*, as did Seebeck et al. (1989).

**Acacia sap**

Only one report has been published of a marsupial feeding on *Acacia* sap; Goldingay (1990) found that *Pet. australis* fed on sap that oozed out as a white foam from glider incisions in the bark of *Acacia* spp. at a coastal site in south-eastern NSW. *Acacia* sap feeding was confined to autumn and spring.

**Acacia seeds**

The consumption of *Acacia* seeds by marsupials appears to be limited. *Pet. norfolcensis* have been observed consuming the green seeds of *A. pyrcahnta* (golden wattle) (Suckling 1995b). There is a single observation of a *Pet. norfolcensis* consuming the seeds and arils of *A. concurrens* (Sharpe and Goldingay 1998). Suckling (1995a) indicated that *Pet. breviceps* use not only the gum but also the green seeds of *A. pyrcahnta* in season. Lindenmayer (1997) reported that *T. cunnunghamii* also consumes *Acacia* seeds in addition to *Acacia* leaves. Two macropods – the rufous hare-wallaby (*Lagorchestes hirsutus*) and the tammar wallaby (*Macropus eugenii*) – have also been reported to consume *Acacia* seeds. *Acacia* seeds are potentially nutritious, containing approximately 23% crude protein, 26% available carbohydrate and 9% fat, but 32% fibre (Brand and Maggiorre 1992), which may be expected to limit nutrient digestibility.

*Lagorchestes hirsutus* is found primarily in arid and semi-arid regions of central Australia, where it lives in spinifex hummock grasslands of sand plain and sand-dune deserts (Lundie-Jenkins 1993). Lundie-Jenkins et al. (1993) reported that *L. hirsutus* were seen consuming seed heads of *A. dictyophleba* "occasionally in season" and the leaves and stems of *A. wiseana* "occasionally out of season." Dicotyledonous species like *Acacia* only constituted a minor part of the diet and were consumed when the quality of other preferred plants declined. The feeding strategy of *L. hirsutus* seems to be flexible and allows the animal to fully utilise those food resources that are available seasonally and in a specific environment.

**Macropus eugenii** is classified as a grazer (Sanson 1978). However, Andrewartha and Barker (1969) found that *M. eugenii* on Kangaroo Island foraged opportunistically underneath A. retinoides trees during the annual summer drought. It appeared that the wallabies were consuming seeds of the legume, potentially as a protein source.

**Acacia arils**

*Acacia* arils are an important food resource for *Pet. gracilis* in north Queensland. Van Dyck (1993) observed *Pet. gracilis* consuming *A. crassicarpa* flowers, possibly for pollen, although there was no discernable nectar production at the time. *A. crassicarpa* produces nectar and pollen in May, and lipid-rich arils are harvested in December (Van Dyck 1993). In summer (November-January), when the pods of *A. crassicarpa* are ripe, the arils become a major food item. Averaged over the year, *Pet. gracilis* spent 74 min per night harvesting flowers (for nectar and/or pollen), 14 min harvesting sap (of *Acacia, Albizia, Eucalyptus*), 20 min harvesting *Acacia* arils, 7 min feeding on mistletoe fruit, 8 min on lerps and honeydew, and 15 min licking manna (Jackson and Johnson 2002). Honeydew is a white encrustation of excess sugar on lerp insects that comes from the large volumes of sap the insects need to consume in order to meet their protein requirements. Manna is also derived from sap; it is formed from sap that exudes at sites of insect damage on tree branches and leaves. There are several dietary items unique to *Pet. gracilis*, including *Acacia* arils, sap of *Eucalyptus* (*Corymbia* intermedia) and *Xanthorrhoea* (grass tree) exudates (Van Dyck 1993). This glider harvests the arils from open pods of *A. crassicarpa*. In some of the *Acacia* species, arils contain 70% lipid on a dry matter basis. *Pet. gracilis* has much to gain by harvesting the *A. crassicarpa* arils in summer (December), when females are lactating and energy requirements are high. *Pet. gracilis* do not eat the *Acacia* seeds, but break them off from the arils and drop them.

*Petaurus gracilis* is clearly dependent on the high lipid and thus high energy content of the arils. This is supported by the documented sighting of a *Pet. gracilis* breaking into an arboreal green ant nest in August to eat arils harvested by the ants (Van Dyck
1993). It was assumed that these arils were harvested by the ants the previous season as there are only three *Acacia* species in the glider area (*A. crassicarpa, A. flavescens* and *A. magnum*) all of which flower in May (Van Dyck 1993). One *Pet. norfolcensis* was observed consuming *Acacia* seeds and arils in northern NSW by Sharpe and Goldingay (1998). These authors described it as an uncommon feeding behaviour.

**Acacia pollen and nectar**

When animals are observed feeding at flowers it is often difficult to discern whether they are selecting primarily for nectar or pollen. Sharpe and Goldingay (1998) evaluated the diet of *Pet. norfolcensis* over 10 months in Bungawalbin Nature Reserve on the north coast of NSW. Nectar and pollen accounted for 59% and arthropods for 26% of observed food consumption.

It is known that *Pet. norfolcensis* will preferentially consume arthropods for protein, but because of the high energy demand needed for collection, they also use pollen when available. In northern and central Victoria, Menkhorst and Collier (1987) observed that *Pet. norfolcensis* consumed coleopteran and lepidopteran larvae obtained from *Acacia* and *Eucalyptus* foliage (based on faecal analyses) as well as plant exudates. The availability of nectar and pollen was not known at the time of the study.

Fleming (2000) observed a *Pe. penicillata* eating fallen 5 cm long inflorescences of *A. diphylla* near Wollomombi Falls in NSW. There is no other documentation of this rock-wallaby consuming *Acacia* flowers or pollen, although flowers of other plant species are consumed. *Acacia* flowers have been seen to be eaten by *Pet. gracilis*, possibly for pollen (Van Dyck 1993); there was no discernible nectar production at the time. There are few other reports of *Acacia* pollen and nectar being consumed by marsupials.

**Acacia as habitat**

Finally, while this review identifies the species that utilise some part of the *Acacia* plant for food, it should be pointed out that the numbers of some marsupial species can be affected by the presence of specific *Acacia* species even though they are not known to consume them. For instance, *M. dorsalis* is a grazer but is closely associated with *A. harpophylla* woodland habitats (Jarman et al. 1991). Other macropods linked with *Acacia* for habitat include the bridled nailtail wallaby (*Onychogalea fraenata*) and the banded hare-wallaby (*Lagostrophus fasciatus*). *O. fraenata* is one of the rarest marsupials in central Queensland (Ellis et al. 1992), and once was the most abundant macropod west of the Great Dividing Range (Dawson et al. 1992). However, with the advent of land clearing for agriculture and the introduction of domestic livestock, this species has been restricted to patches of brigalow (*A. harpophylla*). Likewise, the number of *La. fasciatus* in the south-west of Western Australia has been reduced to zero following the introduction of the red fox (*Vulpes vulpes*). They are now found only on two islands (Dorre and Bernier Islands in Shark Bay, Western Australia). On Dorre Island, the animals shelter in small groups in thick scrub that includes *A. coriacea*, along with other species including *Ficus platypoda*, *Diplolaena dampieri* and *Heterodendrum oleifolium*. On the northern half of Bernier Island they are found in dense shrub made up of *A. ligulata*, *A. coriacea* and *Heterodendrum oleifolium* (Short and Turner 1992). Thus, future survival of *La. fasciatus* seems dependent on *Acacia* habitat.

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