On the ethno-ecology of mallee root-water

James C. Noble and Richard G. Kimber

> The eucalypts of the mallee species thrive in deserts and droughts, but contain water in their roots which only the native inhabitants of the country can discover...A very long root such as I have mentioned might give nearly a bucketful of water; but woe to the white man who fancies he can get water out of the mallee...it is an Aboriginal art at any time or place to find it.
>
> Ernest Giles[1]

> Having cut the root into six-feet lengths and tied them in a bundle, he looped his belt around the bundle and hung it vertically from a tree, the lower ends being placed in the water bucket...Half an hour later we had our first drink and though the water to me seemed slightly woody, it was quite good...Tuck had found these trees often of great value to him. 'Many's the time they've been all I've had—an' don't I know it', he added grimly.
>
> Archer Russell[2]

There is now an extensive literature, based primarily on early historical accounts, describing the ability of Aborigines to live in environments which, when viewed through European eyes, were regarded as quite inhospitable and virtually uninhabitable because of the paucity of drinking water. The frustration experienced by European explorers seeking water in these landscapes is epitomised by an excerpt from Ernest Giles' journal of his 1872 expedition into Central Australia:

> We had wandered amongst such frightful rocks and ungodly places, that I began to think it was useless to search any further for water, but yet the natives were about, burning the grass, and raising fresh fires in all directions; it appeared to me they must get their water from the hollow spouts of some trees, and from the roots of others...I should greatly like to catch a native; I'd walk him off alongside my horse, until he took me to water.[3]

As European exploration of the hinterland gained momentum during the nineteenth century, expedition journals increasingly provided details of the comprehensive

1. Giles 1889, 1, p. 45.
2. Russell 1934, p. 101.
3. Giles 1875, pp. 42, 43.

Aboriginal knowledge of the ecology of these arid communities which enabled them to access various sources of drinking water during their periodic journeys.

> Water is of basic importance for Aborigines and for all the natural species. It is no exaggeration to say that a great deal of their (traditional) everyday as well as religious life is focused on this particular theme...[4]

Such knowledge was particularly important in the semi-arid dunefields and sandplains across much of central and southern Australia where many vegetation communities were dominated structurally, and floristically, by multi-stemmed mallee eucalypts (*Eucalyptus* spp.) (Figure 1). Here permanent sources of water in the form of natural wells[5] and 'soaks' were comparatively rare because of the generally porous nature of the soils and resident Aborigines often relied instead on a particular source, the 'water mallee', to provide much of their drinking water. To the astonishment of early European observers, the roots of such mallees were seen to provide abundant quantities of clear, usually tasteless, drinking water shortly after being dug up by Aborigines.

After first describing the distribution of Aborigines throughout the mallee and the original perceptions of these landscapes by European explorers, the anatomy and morphology of eucalypt root systems will be briefly described before presenting some empirical data on the morphology of mallee root systems, root-water contents and stem xylem water potentials (ψ_x) obtained during ecological studies undertaken over a ten-year period (1977-87). These will also include root-water data obtained in collaboration with Aborigines in South Australian mallee country near Yalata. The results of these studies will finally be summarised and discussed in the context of a conceptual framework describing the development and distribution of water mallees.

Aborigines in the mallee

During the early part of the nineteenth century, anthropologists recognised a distinct group of Aborigines located along the lower Murray Valley:

> The terms *Mallegoondeet* and *Millegoondeet* are very precise in their application, as indicating the men of the *Malle* country, or the inhabitants of the banks of the Murray, which is known for a very considerable portion of its stream, by the native name of *Mille*.[6]

The mallee dwellers of southeastern Australia were still recognised a century later by Tindale as constituting a distinct ecological group.[7]

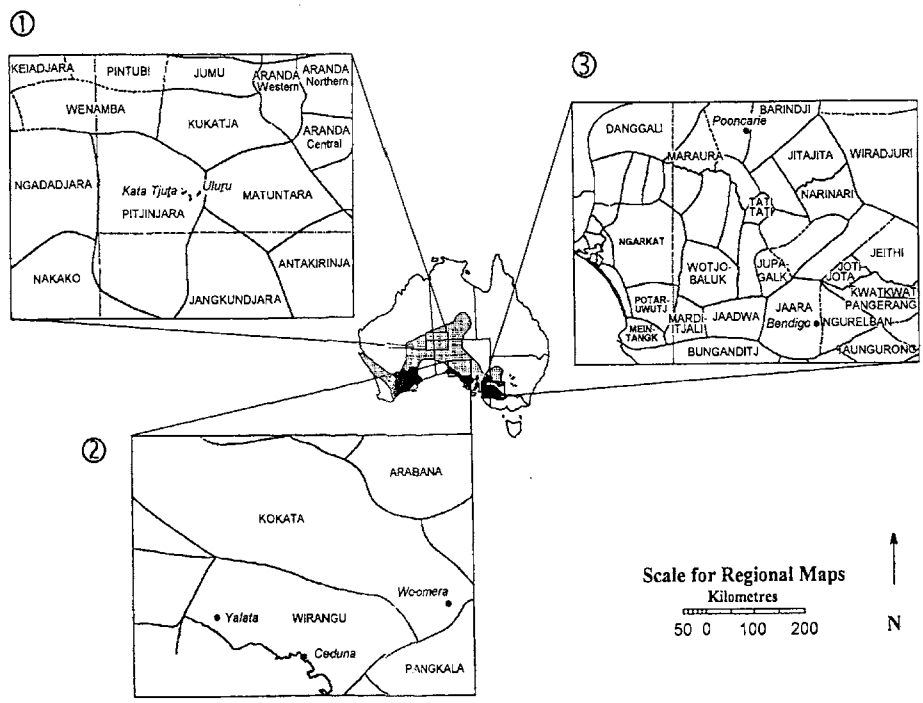
> The Ngarkat north of the Tatiara country on the borders of South Australia and Victoria were at home only in territory covered by low-growing mallee (*Eucalyptus* spp.) scrub, on whose water-bearing roots they were utterly dependent for liquid on an otherwise almost waterless karst plateau...The aborigines of the mallee scrub belt...[have] abilities as pragmatic ecologists...The Ngarkat people could tell by the stars when different plants were ready for harvesting and they made long journeys to get the food. Water was from mallee roots during these journeys.[8]

4. Berndt 1972, p. 179.
5. Cunningham 1973, pp. 365–9.
6. Parker 1854, p. 12.
7. Tindale 1959, p. 41.
8. Tindale 1974, p. 134.

Unlike the more sedentary riverine groups, they often spent indefinite periods 'inside' until forced out by extended drought periods. They could then only gain access to perennial streams or permanent waterholes by following clearly defined paths designated by the riverine Aborigines who referred to the visitors as *Malikuunditj*,[9] the same as *Malleegoondeet*, and usually pronounced as 'Malleegunditch'.[10]

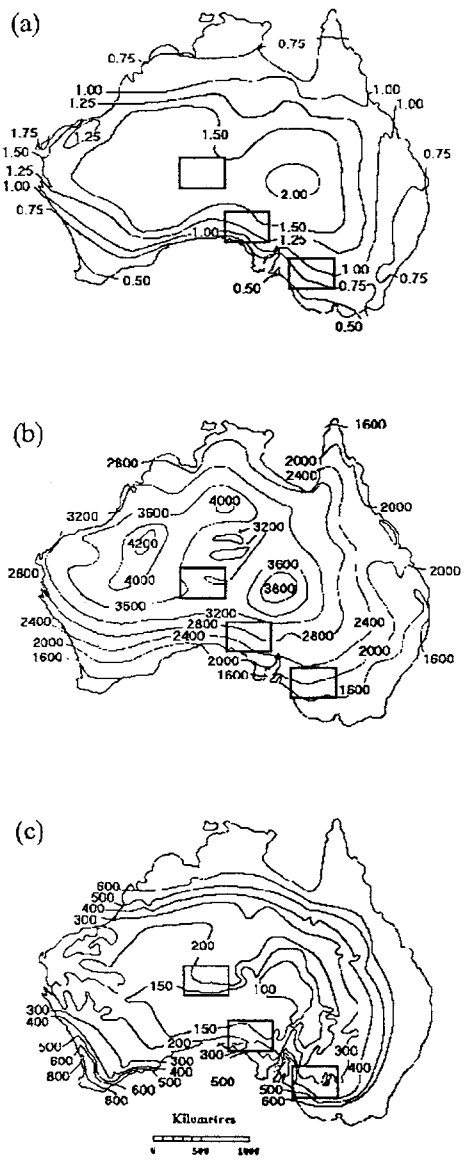
The distinctiveness, and ecological diversity, of the areas occupied by Aboriginal groups in the southeastern mallee are obvious in Figure 1 where there are clearly more distinct areas delineated in region 3. Whether this diversity reflects some degree of ecological specialisation amongst mallee dwellers, or whether it was due more to the presence of the Murray river, is uncertain. Nonetheless, the higher density of discrete Aboriginal groups in this Region (>30 compared with 5–10 in the other two Regions) suggests that Aboriginal people found these mallee/riverine regions far from unproductive. Tindale estimated average population size of most Aboriginal groups to be around 450;[11] the overall population carrying capacity of Region 3 appears to be substantially higher than the other two, possibly partly due to a more favourable climatic regime as well as a more productive riverine environment (Figure 2).

Figure 1 Locations of three sets of Aboriginal groups by region: Region 1, Region 2 and Region 3



9. ibid., pp. 62, 65.
10. The suffix '*gundidj* simply indicates 'people from' and is found in many names of Aboriginal groups in Victoria, e.g. *Yambeet-gundidj* (L. Hercus, pers. comm.).
11. Tindale 1974, p. 110.

Figure 2 Locations of the three Aboriginal groups along three climatic gradsects (a) annual rainfall variability (<0.5=low & > 2.0=high); (b) annual evaporation (mm), and (c) median annual rainfall (mm) (After Parkinson 1986)



In this study the three regions were deliberately selected along a northwest-southeast axis to compare Aboriginal groups in areas differing in relative importance of mallee communities. Region 1 exemplifies an area where mallee was significant but not predominant; Region 2 an area where part only comprised mallee-dominant areas; and finally Region 3 typifies an area where mallee vegetation was generally predominant throughout. The regions were also aligned along a rainfall gradient-oriented transect, with the least arid located in the southeast (Region 3) and the most arid (Region 1) at the north-western end of the transect.

Malikuunditj was probably a regional name used in a rather loose way by several distinct groups. The Wotjobaluk, for example, whose base was primarily the Lake Hindmarsh area (Figure 1, Region 3) where there was abundant water and food, might have used the word when referring to others in the same Region such as the Ngarkat to the west, implying that they were from an area of mallee scrub with inferior resources. The latter, in turn, could have used the word when referring to the Wotjobaluk, as well as other tribes such as the Baraparapa to the east in what is now the Cohuna district of northern Victoria, because they felt their own productive areas of country the best in the Region.

Although use of the term *Malikuunditj* was not recorded by Tindale in other mallee areas of

Australia, 'mallee' was certainly widely used in the context of the water mallee. The Kokata territory north-west of Woomera for example (Figure 1, Region 2), an area described by Tindale as '...some of the most inhospitable country in Australia',[12] is drawn out in another ecotonal relationship along the 'belt of forested mallee country' since the water-bearing mallee roots...

> determine not only their patterns of living but also influence their need for sufficient amicable relationships with surrounding peoples to enable them to repair to permanent water supplies in times of drought.[13]

The Kokata comprised a community of around 450 people who migrated south from an area northwest of Lake Gairdner before settling in the Woomera area in the second half of the last century. Unlike the few large groups of 600 or so people such as the Wiradjuri, Kamilaroi, Walpiri and Wadjari, they were unable to exploit a wider variety of foods, especially plant foods, and were thus unable to hold a larger group of people together as a single community.[14] Wirangu people—the original inhabitants of the Yalata area—often talk about 'water trees', and mention particularly the 'red mallee' *ngapari*, also called *gangu* or 'kung mallee', which they say mainly occurred in the northern parts of their country. Kokata people came gradually into the area and continued the practice of using the red mallee.[15]

There is little doubt therefore that most Aboriginal groups, including those of non-mallee areas, throughout semi-arid and arid Australia were aware of the existence of drinking water in the roots of certain mallee eucalypts, as well as individuals of other tree species. However, local knowledge of the general proximity of such trees remained of paramount importance when travelling along established trade routes.[16] Aboriginal people travelling through unfamiliar territory were still exposed to considerable risk, especially during hot weather. In October 1963, a family group of six Aborigines near Laverton in Western Australia attempted to walk to Cundeelee, a locality never previously visited by any of them.

> The group travelled west along the Laverton–Maralinga track and turned south at Neal Junction. The going became hard and they found no waterholes. The water trees petered out.
>
> Three of the group subsequently perished and the rest struggled on until much later they...found some water trees, dug the roots with sticks, and sucked the sap from them.[17]

European perceptions of the mallee

Aborigines clearly used, and still use, the term 'mallee' in a quite specific sense to describe a particular individual within a local population of multi-stemmed eucalypts. In contrast, Europeans have generally used 'mallee' in a much broader sense to define either plant communities dominated by populations of multi-stemmed eucalypts, or

12. ibid., p. 213.
13. ibid., p. 114.
14. ibid., pp. 110–11
15. L. Hercus, pers. comm. *Ngapa* is the word for water throughout the Lake Eyre Basin.
16. Johnston 1941, pp. 33–5.
17. Allan 1964, p. 34.

geographical regions, as in the Victorian Mallee. Despite the large mallee regions across southern Australia, substantial areas of it also occur throughout central areas of the continent. These were first described by Giles in the mid-1870s in somewhat indifferent terms after travelling through

> the dreary scrubs covered with the normal timber—that is to say, a mixture of the Eucalyptus dumosa or mallee, casuarinas or black oaks, ... the sight of the country from any of these hills is truly frightful; it seemed as though the scrubs were to end only with our journey.[18]

Part of this antipathy was due to the underlying 'hideous spinifex, which both we and the horses dread like a pestilence'.[19]

These communities were subsequently described twenty years later in more prosaic style by Baldwin Spencer, leader of the Horn Scientific Expedition to Central Australia in 1894:

> For the first time also we met with *Eucalyptus gamophylla*, one of the Mallee gums, that is, those which have a bole or bossy stem often not conspicuous above the ground from which arise a number of small branches.[20]

This coppicing growth habit of mallee eucalypts, when combined with the confinement of the terminal foliage to a narrow canopy zone, characterises the distinctive appearance or *facies* of these unique communities which have traditionally been regarded as transitional between the arid or Eremaean zone and the sclerophyll forests of more humid regions.[21]

One of the earliest references in European literature occurred in Westgarth's *Australia Felix*,[22] published in 1848, describing how the '...Wimmera...traverses a region of sand and heath, succeeded by jungle and *mallee* scrub...[*Note*] Eucalyptus dumosa.' Europeans however, initially spelt the word in remarkably different ways. *The Australian National Dictionary*[23] records an even earlier newspaper reference in *The Standard* (Melbourne) of 7 June, 1845 (2/6)—'The stock...are with all possible expedition driven into an almost impenetrable scrub, termed by the natives "Malley"'. Later, *The Port Phillip Herald* of 16 March, 1847 (2/5) recorded how 'The place of habitation of this interesting reptile [*sc.* the Mindai] is the Marlis or as it is perhaps more properly called in Mr Ham's new chart—the Mallee Scrub'. Kenyon later referred to Ham's map of 1846 which '...gives the present spelling and states that it was the name given by the blacks to the Eucalyptus Dumosa (*sic*)'.[24] Kenyon also described how Henry Wade, the surveyor responsible in 1847 for delineating the boundary line separating Victoria and South Australia, first spelt it 'Marlie' and later 'Marlee'.[25]

While Edward Eyre was the first to record Aborigines extracting root-water from mallee eucalypts following his epic journey across southern Australia in 1840–1,[26]

18. Giles 1889, II, p. 232.
19. ibid I, p. 56.
20. Spencer 1896, p. 59.
21. Wood 1929, p. 363.
22. Westgarth 1848, p. 27.
23. Ramson 1988, p. 383.
24. Kenyon 1916, p. 42.
25. ibid., pp. 2–3.

Mitchell had earlier described Aborigines obtaining drinking water from roots without actually specifying the types of trees involved.[27] In Victorian mallee communities, early European observers such as Cairns[28] referred to 'weir mallee' while much later Massola[29] claimed water was '...also obtained from the roots of some of the eucalypts, which the natives called Weir-mallee.' Beveridge[30] described yearly journeys through '...the very barrenest portion of the barren Mallee Scrub' undertaken by Aborigines travelling to a dry lake whose sediments contained a bright red ochre used for decorating their bodies and 'opossum' cloaks. When their supplies of water contained in wallaby skin bags ran dry, they resorted to '...the root of a peculiar kind of mallee, which they call *weir*, from whence they obtain a supply of sweet and limpid water, even in the warmest weather'.

Ernest Giles and subsequent explorers, as well as early natural historians and anthropologists such as Stirling,[31] also provided later accounts of water being extracted from roots of other trees including non-mallee eucalypts such as black box (*Eucalyptus largiflorens*) and non-eucalypts such as desert kurrajong (*Brachychiton gregorii*) and needlewood (*Hakea leucoptera*). According to Anderson[32] the latter tree is '...one of the western species from the fleshy roots of which water can be obtained, the aborigines digging up the roots and placing one end in slow fire.' This however, was the only reference seen in the literature regarding the use of fire to assist in the extraction of root water. References to root-water, and particularly mallee root-water, published over the past 163 years are shown in Appendix 1. Despite this extensive historical record, there are probably few, if any, non-Aboriginals today capable of identifying water mallees in the field with any degree of confidence.

Mallee root anatomy

The root is a fundamental component of the whole plant performing several major functions including anchoring the plant to the soil, absorbing any available nutrients and water present in the rhizosphere, as well as providing habitat for a wide range of soil micro-organisms. The close relationship between plant and soil originates with the primary root or radicle emerging from the germinating seed.

The radicle first emerges as a simple cylindrical structure but with subsequent secondary growth, particularly in perennial species, clear tissue differentiation occurs. These tissues, characterised by distinctive cell types, are comprehensively described in most botanical texts.[33] Secondary root growth following division of cambial or meristematic cells generally results in new cells maturing either as secondary xylem or as secondary phloem elements. In this paper attention will be focussed on those found in the xylem because they conduct water and minerals from absorbing root surfaces.

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26. Eyre 1845, pp. 244, 254.
27. Mitchell 1839, pp. 196, 199.
28. Cairns 1858, pp. 22–5.
29. Massola 1966, p. 270.
30. Beveridge 1889, pp. 27–28.
31. Stirling 1896, pp. 65–66.
32. Anderson 1947, p. 14.
33. Esau 1977, pp. 215–54.

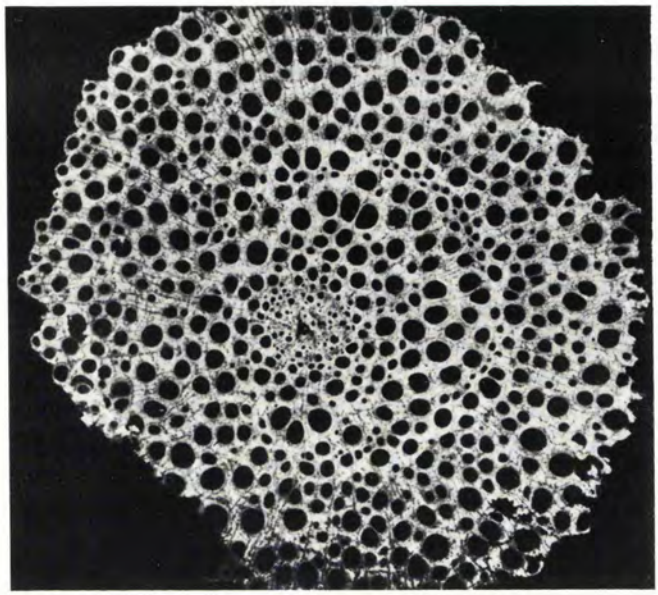

Figure 3 A small water-bearing root of the mallee *Eucaluyptus transcontinentalis* (syn *E. oleosa*) from Ooldea, South Australia. The root was 5.5mm in diameter with an available pore area of 32.3% (after Cleland 1939).

The cells produced in the secondary xylem tissue are characteristically hard and heavily lignified vessel elements or tracheids in contrast to the thin-walled, delicate phloem elements. In mature mallee roots, xylem tissue develops through slight shortening and widening of individual cells combined with perforation, or even complete loss, of the end walls or septa. These modified cells ultimately form pipe-like structures called vessels (Figure 3)—the larger the plant, the larger the root and its constituent vessels, some reaching one metre in length and 8 mm in diameter following secondary growth (D.J. Carr, pers. comm.).

Mallee root architecture

As an individual plant develops over time, the root system develops a particular morphology or architecture[34] which, whilst not necessarily species-specific, may often characterise a particular functional group or guild. These differences in morphological traits may contribute to an individual's ecological fitness enabling it to grow and reproduce more successfully than other plants in particular environments. The effectiveness of a root as a 'forager' for resources will depend strongly on its architecture although root systems are less rigidly programmed than shoot systems.[35]

Root system dynamics of seedlings and annual plants can be readily quantified experimentally using hydroponics or root observation boxes (rhizotrons). However, they all have serious shortcomings since none realistically replicate the heterogeneous, three-dimensional nature of soil.[36] Three-dimensional studies of mature and large perennial, woody plants such as the mallee eucalypts, are extremely difficult to undertake in the field. Consequently the efforts required to safely excavate the substantial volumes of soil necessary to even partially expose individual root systems of established trees and shrubs,[37] are usually strenuously avoided.

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34. Bell 1991, pp. 100–1.
35. Begon et al. 1990, pp. 94–5.
36. Harper et al. 1991, pp. 3–7.
37. Mackie-Dawson and Atkinson 1991, pp. 25–30.

Natural erosive processes occasionally expose the architecture of root systems to a considerable depth.[38] For example, root systems of mature mallee eucalypts can often be delineated following streambank erosion of cliffs along the Murray River. As shown in Fig. 4, there are two major types of roots in mallee eucalypts, shallow plagiotropic roots which extend horizontally, and deep geotropic roots.

The two root types are often discriminated on a functional basis however, as pointed out elsewhere,[39] much has still to be learnt about the functions of morphologically dissimilar roots in eucalypts. Geotropic roots are commonly called 'sinker roots' because their main functional attribute is generally ascribed to their ability to extract soil moisture from as deep as 28m.[40] Tree and shrub species possessing this latter capability are commonly described as phreatophytes.

Figure 4 View of the root system of an established pointed-fruit mallee (*Eucalyptus socialis*) at 'Kerribee' west of Euston, N.S.W. showing horizonta 'feeder' roots and vertical 'sinker' roots.

An additional feature of mallee eucalypts is their ability to store soil moisture in significant quantities as free, gravitational water in shallow, lateral roots. Some individuals, because of the long vessels found within large roots, are capable of storing significant volumes of free, gravitational water. In some ways, this capacity to tap into water reserves at depth and then store it close to the surface is not unlike the phenomenon of hydraulic lift[41] whereby subsoil moisture absorbed by deep roots is elevated and then released in the upper soil profile during the night to be later resorbed by roots during the following day. This nocturnal efflux of water from surface roots may also flush localised depletion zones surrounding roots thereby enhancing nutrient uptake in drying soils.[42] By measuring oxygen stable isotope ratios of water within plants, it should be possible at some future stage not only to determine the sources of water stored in mallee roots, but also to provide information on competitive interactions and water use patterns under natural conditions.[43]

38. Cremer 1993, p. 43.
39. Tippett and O'Brien 1976, pp. 619–20.
40. Nulsen et al. 1986, p. 365.
41. Caldwell and Richards 1989, p. 1.
42. Dawson 1993, p. 573.
43. Walker and Richardson 1991, pp. 148–55; Ehleringer and Dawson 1992, pp. 1077–8.

Another phenomenon which has received very little attention for water relations of mallee eucalypts is root fusion. In a way, this resembles a form of clonal growth whereby two genetic individuals or 'genets' become a single physiological 'individual' because of significant interchange of water and nutrients. Root fusion has been recorded between mature trees of mountain ash (*E. regnans*) with living bark persisting on leafless stumps for at least 40 years where adjacent vigorous trees are growing within a radius of 1-2 metres.[44] Live stumps, where the bark growth has completely covered the top of the stumps, presumably due to root fusion, have also been observed by one of the authors (JCN) in softwood forests in eastern New South Wales.

Whether such linkages occur frequently, or at all, between mallee eucalypts has yet to be established but if they do occur, the ramifications for the growth and survival of linked plants in these arid climates could be profound. Studies of root systems in comparable Mediterranean-type communities in both Californian chaparral[45] and Chilean matorral[46] have found a low incidence of root fusion. These findings lend support to the hypothesis that root fusion is likely to have greater adaptive significance by providing increased anchoring in tree communities subjected to high winds, especially where root systems are relatively shallow because of either high water tables or bedrock close to the surface.[47]

Mallee trees and shrubs in Western Australia effectively redistribute 8% of the annual rainfall with 3% lost as interception and 5% ending up as stem flow. On an individual shrub/tree basis however, around 15% of the rain falling on the canopy can be lost as interception while 25% flows down the stem.[48] This stemflow may enable significant accession of rainwater to subsoil moisture reserves via annular pathways of the rhizosphere surrounding sinker roots thereby circumventing any water repellence imposed by hydrophobic soils commonly found in mallee hummocks.[49]

Field studies of water mallees

(i) Root-Water at Yalata, South Australia

In February 1981, preliminary field observations of water mallees were undertaken in collaboration with two local Aborigines, Messrs Jack May and Hugh Windlass, in mallee country approximately 30 km northwest of Yalata (31°29'S, 131°51'E). The first water mallee sampled was a large pointed mallee (*Eucalyptus socialis*) (Figure 5) bordering an extensive grassland plain dominated by speargrass (*Stipa* spp.).

After a brief preliminary examination of the tree and local surroundings, the two men, both of whom carried short steel bars or jemmies, then proceeded to slowly circle the tree at a radius of approximately 10–15 metres out from its base while closely examining the soil surface. On sighting an imperceptible surface irregularity, presumably in the form of a very slight rise, the jemmy was then jabbed into the ground (Figure 6a). An underlying root was found, the jemmy was used to scrape away the surface soil,

44. Ashton 1975, p. 877.
45. Saunier and Wagle 1965, p. 750; Kummerow et al. 1977, pp. 174–6.
46. Hoffman and Kummerow 1978, p. 67.
47. Keeley 1988, p. 366.
48. Nulsen et al. 1986, pp. 367–8.
49. Bond 1964, p. 123; Anon. 1972, p. 2; Wetherby 1984, pp. 1–2.

Figure 5 A water mallee (*Eucalyptus socialis*) growing on the margin of an open area in a mallee community near Yalata, South Australia.

and the exposed root was then severed with a tomahawk. The end of the severed root was then grasped in both hands and prised up until approximately four metres of root lay on the surface (Figure 6b). The excavated root was cut into four segments, each *c.* 1 m in length, which were then held vertically over a billy to collect the freely running water (Figure 6c). Approximately two minutes later when only occasional drips were falling, the segments were placed in large, double-thickness plastic bags and sealed with rubber bands.

Water volumes collected in the billy were recorded using a measuring cylinder and water samples placed in small plastic containers for later chemical analysis. Root samples were likewise taken from two smaller water mallees and from three non-water mallees nearby (duplicate roots from each replicate shrub).

Four surface-soil samples (0–10 cm) were also taken adjacent to each root sampled and sealed in smaller, double-thickness plastic bags. Soil and root samples were weighed before and after oven-drying (24 hours at 95°C) upon returning to the laboratory. Total root length of each sample was also measured.

Percent water content of water and control mallees at Yalata did not differ significantly (Figure 7a); however significantly more water per unit length of root was held by water mallees (Figure 7b) due to their larger roots and constituent vessels. Although the root-water was quite clear when it was first collected, it rapidly became brownish after an hour or so of exposure to sunlight, due possibly to precipitated tannins although the taste remained unaffected. Tietkens[50] also recorded that water obtained from desert oak (*Casuarina decaisneana*) in Central Australia '...is cool—quite cool—colourless and refreshing; but I have noticed that upon exposure to the air for a few hours it becomes a

Figure 6a: On sighting the root, the jemmy was jabbed into the ground.

Figure 6b: About four metres of severed root were prised out of the ground.

Figure 6c: The root is held over the billy to collect the water.

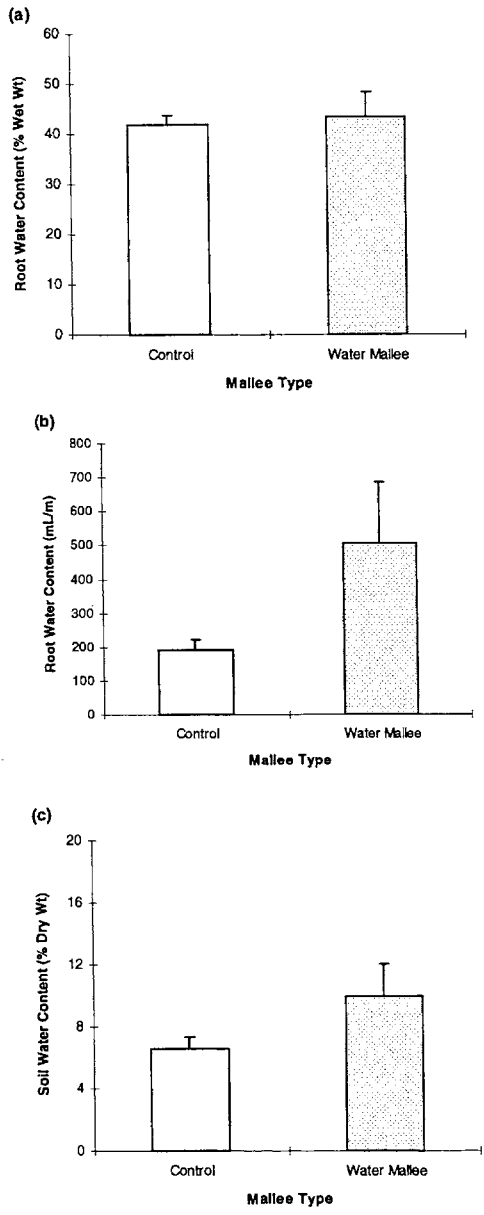

Figure 7 (a) Percent root-water contents of water and control mallees at Yalata; (b) comparative root-water volumes per metre root segment; and (c) comparative surface-soil (0–10 cm) water contents adjacent to root sampling sites

pale-brown colour, such as would be noticed in water into which a piece of bark had been dropped'.

Subsequent analysis of root-water samples obtained from the three water mallees at Yalata showed a surprisingly wide range in both pH (5.27, 6.81 and 7.23) and electrical conductivity (451, 570 and 1,166 µS respectively), possibly reflecting variations in site quality. The best water quality was undoubtedly that obtained from roots of the first water mallee sampled (Figure 5).

The water contents of surface soils adjacent to water mallees at Yalata were also higher than those adjoining control mallees (Figure 7c). Whether these differences could be attributed to hydraulic lift and efflux of water from surface roots is not known. Tracer techniques such as deuterium (D_2O) labelling of roots[51] may resolve the issue. Differences in soil depth or more efficient capture of surface runoff may also have an influence on localised soil water storage.

(ii) Root-water at Pooncarie, New South Wales

Several large paddocks on 'Birdwood' Station near Pooncarie ($33^0$24'S, $142^0$36'E), a site of intensive field studies into mallee fire ecology,[52] were surveyed from internal roads and tracks nine months later to determine

50. Reported also in Magarey 1895, p. 650.
51. Caldwell et al. 1991, pp. 423–4.
52. Noble 1989a, pp. 170–8; 1989b, pp. 170–5; Noble and Vines 1993, pp. 271–6.

Figure 8 (a) Above, a putative water-mallee (*Eucalyptus socialis*) located on 'Birdwood', Pooncarie, N.S.W.; and (b) Below, gravitational water running freely from a relatively small root of the same mallee tree.

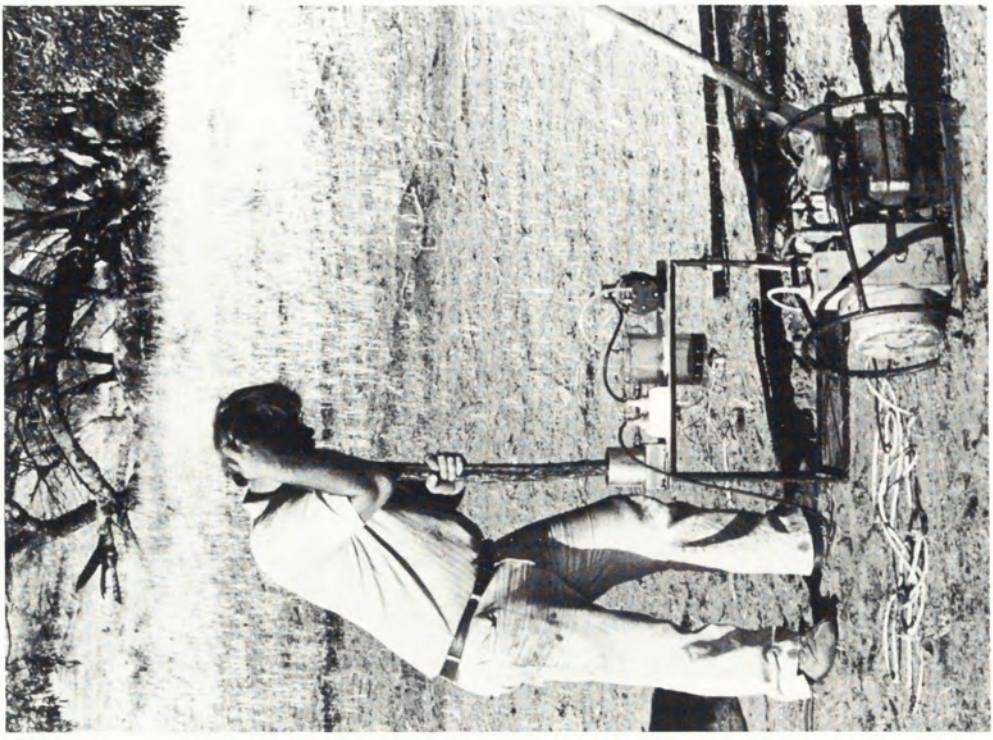

Figure 9a (left) and 9b (right)

whether the information gained from Yalata could be used to identify potential water mallees. This pilot survey resulted in only four individuals being selected for testing. One particular mallee (*Eucalyptus socialis*) in Back Paddock (Figure 8a and 8b) possessed lateral roots that readily provided freely running water. In addition, the discovery of a substantial portion of a grinding stone near the base suggested that the tree may have been an important Aboriginal site in the past.

Some mallee root-water can be obtained by blowing into one end of a severed root (Figure 9a) although it is hard work. Accordingly, a zero vacuum pump was constructed using a small (2 Kva) portable generator driven by a 189 W petrol engine (see Figure 9b). Root-water extracted passed through a 12 mm diameter tube into a thick-walled perspex cylinder (10 cm diameter and 20 cm deep) where it could be bled directly into a measuring cylinder through a tap.

Root-water content obtained per vacuum indicated clearly that the roots of the first water mallee, where the stone artefact was found, contained considerably more gravitational water than the other water mallees despite the latter having higher water contents per unit root length (Table 1).

Table 1 Root-water obtained from four water mallees at 'Birdwood' station, Pooncarie, NSW

	Water extracted per vacuum (mL/m root)	Vacuum-extracted water (% total water content	Total water content after vacuum extraction & ovendrying (% wet wt)	Total root-water content (mL/m)
Back paddock				
large root (5 cm)	70.7	24.2	55.4	292
small root (2 cm)	7.5	7.1	38.5	106
Mallee Vale Tank	36.7	9.6	45.3	382
Mallee Vale Soak	22.0	9.4	51.0	235
Mallee Vale Flat				
10 m from base	17.0	4.8	33.6	558
15 m from base	58.0	10.3	34.4	563
19 m from base	6.5	2.4	31.8	275

(iii) Physiological benefits

Any ecological or physiological benefits resulting from these comparatively high root-water contents are difficult to ascertain. Given that wildfires generally occur in the summer when temperatures are high and soil water levels are low, one reason for the mallee's ability to refoliate so quickly after such fires may be the proximity of these 'reservoirs' of free water. Further, water mallees with their higher volumes of free root-water may be even more resilient to periodic fire.

In November 1991, the plant-water status of mallee plants growing in contrasting fire treatments was measured on 'Birdwood'.[53] Dawn xylem water potential (ψ_x) of shoots taken from smaller 'whipstick'[54] mallees showed little variation, irrespective of fire history, averaging -4.3 Mpa. Nonetheless, ψ_x was significantly higher (-2.9 MPa) in shoots taken from water mallees (Figure 10). Similar results were obtained for mallee seedlings and coppices in Wyperfeld National Park[55] while the dawn water potential of another mallee species, *Eucalyptus behriana*, growing near Melton, 40 km northwest of Melbourne, ranged from -2.0 to -4.4 MPa according to season.[56]

Table 2 Measurements using roots from three species of burnt and unburnt mallees at 'Birdwood', Pooncarie, NSW

(i) Burnt	*E. dumosa*	*E. socialis*	*E. foecunda*
Mean root diameter (cm)	1.7	2.0	1.2
Dry wt/length (g/cm)	2.9	1.5	1.0
Water content (% wet wt)	21.7	38.7	43.7
Water volume (mL/m)	79.7	95.3	75.6
(ii) Unburnt			
Mean root diameter (cm)	1.7	1.7	-
Dry wt/length (g/cm)	2.2	2.3	-
Water content (% wet wt)	39.4	39.9	-
Water volume (mL/m)	140.6	152.2	-

Because it has been suggested elsewhere[57] that root dysfunction may be responsible for inducing mortality of mallees subjected to multiple decapitation by fire, roots of mallees at 'Birdwood' with contrasting fire histories were also sampled by mechanical means prior to ovendrying to see whether root-water contents varied markedly. Results obtained from these preliminary observations suggest that, as at Yalata, there were no major differences between burnt and unburnt mallees, in terms of percent water content. Despite the limited number of water mallees sampled, it is apparent that water volumes per unit root length had declined substantially, by 43-66%, in the burnt mallees (Table 2).

Conclusions

During the 60,000 years or so of their occupation of this continent,[58] Aborigines have acquired a remarkable ability to recognise, and often manipulate, many complex ecological processes and their interactions throughout a wide range of ecosystems. On this basis, they have often been described as the original Australian ecologists[59] who, prior to the arrival of Europeans, had successfully adapted to what in today's parlance would be described as 'sustainable land use' although it appears that they may also have been involved in the extinction of some of the megafauna surviving the late Pleistocene.[60] As Tindale[61] has pointed out, '...the dominant factors enabling survival [of Aborigines] in

53. Using an established technique (Scholander et al. 1965, pp. 339–42, Ritchie and Hinckley 1975, pp. 165–250), dawn stem xylem water potential (ψ_x) was measured by sampling terminal shoots from replicate plants in the following treatments: (i) unburnt controls; (ii) burnt once three years earlier (1978); and (iii) burnt twice at two-yearly intervals (1978, 1980). Shoots (7–10 cm in length) were cut from mallee coppices regenerating after fire and lower leaves removed until 5–6 terminal leaves remained, and the lower ends of shoots immediately placed in the pressure bomb to record ψ_x. Replicate shoots of water mallees were also obtained by firing a shotgun into the taller canopies. Sampling commenced at 0500h and finished at 0630h.
54. Noble and Mulham 1980, p. 127.
55. Wellington 1984, p. 362.
56. Myers and Neales 1984, pp. 498–505.
57. Noble 1982, p. 158.
58. Roberts et al. 1994, pp. 575–6; Chappell et al. 1996, pp. 543–4.
59. Tindale 1959, pp. 40–2; Tindale 1974, pp. 110–11.
60. Flannery 1994, pp. 199–207.
61. Tindale 1959, p. 40.

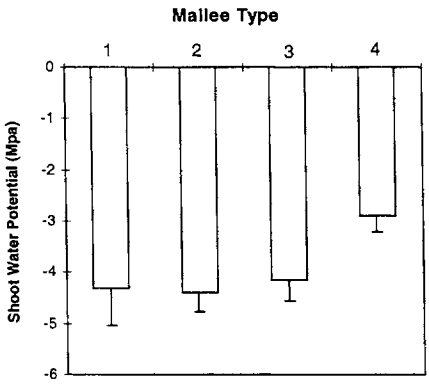

Figure 10 Dawn xylem water potentials (ψ_x) of shoots from smaller mallees of differing fire histories and larger water mallees at 'Birdwood', Pooncarie. Key to mallee types: (1) Unburnt mallee controls; (2) Coppices of mallee burnt once three years previously; (3) Coppices of mallee burnt one and three years earlier; (4) Unburnt water mallees

the Australian environment revolved around the successful maintenance of four chief items—food, water, shelter, and territorial integrity. 'Sadly, there is little understanding today of how Aborigines coped in meeting these needs in mallee communities. This is especially so in the mallee-dominant ecosystems of southern Australia which have been massively transformed by European agricultural systems and where much of the traditional ecological knowledge has either disappeared entirely, or is rapidly disappearing.

Because water mallees are generally scarce, or of low density, it is difficult to undertake demographic studies which would indicate the critical factors regulating their distribution, abundance and population regulation in different mallee ecosystems. A preliminary conceptual approach to modelling the population ecology of water mallees is shown as a flow diagram or state framework[62] in Figure 11 illustrating the complexity of various factors dictating the probability of a water mallee establishing in an appropriate niche. Not only does the initial fire disturbance need to be of sufficient intensity to promote the necessary seed rain required to swamp the ant harvesters, usually referred to as predator satiation,[63] but timing and intensity of subsequent rainfall events is critical. While such events are essential to promote germination during optimum soil temperaturesl, some seed may also be dispersed by rainfall redistribution to 'safe sites' where there is minimal interference from established plants, either in gaps following death of old individual mallees or along the ecotones where shrubland communities adjoin open grasslands. Finally, any seed germinating in such favoured sites must also have the necessary genetic potential or fitness required to develop into a water mallee.

A search of the relevant literature initially suggested that the Australian Aborigines were unique in their ability to extract free-running water from tree roots. It is of interest to note however, that the indigenous inhabitants of northern Cameroon can access drinking water from the surface (0–20 cm) lateral roots of the shrub *Lannea humilis*, and possibly other *Lannea* species as well (J. Seghieri, pers. comm.). These shrubs generally grow on highly degraded soils and possess roots with specialised water storage organs, visible as swollen sections or root bulges (Seghieri 1995), which yield free drinking water after cutting.

62. Westoby et al. 1989, pp. 269–70.
63. O'Dowd and Gill 1984, p. 1052; Wellington 1989, pp. 158–9.

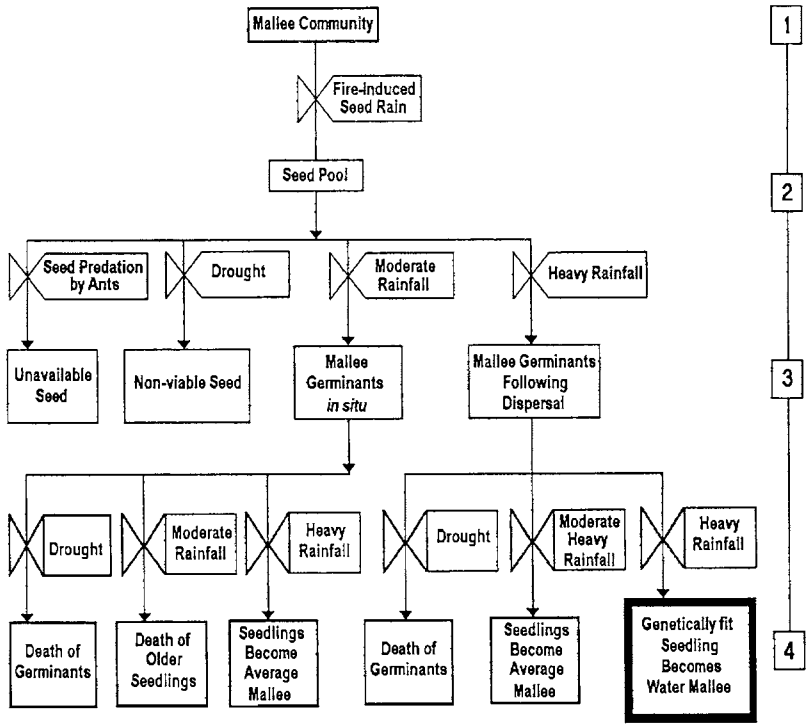

Figure 11 A framework for the population ecology of water mallees.

Whilst the roots of some plant species growing in the Kalahari Desert, particularly *Raphionacme burkei* and *Tylosema esculentum* are sometimes so moisture-filled that the water literally drips out of them (R. Hitchcock, pers. comm.), mostly the !Kung have to first cut up the roots and tubers of these and other species such as *Coccinia rehmanii* and *Citrullus lanatus*, before then squeezing the moisture out.[64] Even then, the roots of *Citrullus lanatus* are only utilised in periods of severe drought when people are under stress because it is so bitter (R. Hitchcock, pers. comm.). Similarly, although *Raphionacme burkei* is very valuable because of its moisture content and general abundance, the moisture extracted is often so bitter that it has to be sweetened with *Terminalia* leaves.[65] No record could be found of Native Americans using root water for drinking purposes although the Seri Indians of northwestern Mexico obtained water by macerating stems of the barrel cactus (*Ferocactus wislizenii*) as an emergency source of water.[66]

64. Silberbauer 1981, pp. 275–7.
65. Campbell 1986, p. 83.
66. Felger and Moser 1985, pp. 262–3.

> The Aborigines of today are not survivals with a stone-age culture. They are our contemporaries, modern men and women, motivated by the same basic urges as ourselves, but with a different way of living, a different outlook, different values. And difference does not, necessarily, imply inequality.[67]

It is our hope that this review will promote future ecological, ecophysiological, and ethno-ecological studies of the water relations of mallee eucalypts, particularly in the context of their utilisation by Aborigines. Preferably such studies will be undertaken with the active collaboration of those people who continue to rely on these unique resources scattered throughout arid Australia.

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67. Berndt and Berndt 1964, p. 8.

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Appendix
Chronology of published observations on the collection of root-water

1832, Bogan River, east of Nyngan, NSW

'We saw, that around many trees, the roots had been taken up, and we found them without the bark, and cut into short clubs or billets, but for what purpose we could not then discover.'

'They seemed busy, digging at the root of a large tree...I discovered that they dug up the roots for the sake of drinking the sap. It appeared, that they first cut these roots into billets, and then stripped off the bark or rind, which they sometimes chew, after which, holding up the billet and applying one end to the mouth, they let the juice drop into it.' (Mitchell 1839, pp. 196, 199)

1840–41, Vicinity of Mount Barren, WA

'...their experience at once points out to them the lowest levels where the gum-scrub grows, and where they are sure of getting water from its roots, with the least possible amount of labour...'

'In cases of extreme thirst, ...the toil of digging for the roots would be well repaid by the relief afforded. I have myself, in such cases, found that though I could by no means satiate my thirst, I could always succeed in keeping my mouth cool and moist...' (Eyre 1845)

1853, Murray River

'With respect to the 'Mallee', which covers so large a portion in the vicinity of this river, it may not be uninteresting to mention that there is a root of a particular kind of this shrub well known to the natives, which being cut into strips and placed in a pannikin or other vesel, has the property of exuding water from within, which slowly dropping out of the wood, is thus preserved for the thirsty traveller.' (Kinloch 1853)

1858, Murray River, Victoria

'During a recent visit to the Murray, where I had often heard of this useful shrub, my friend, Mr Peter Beveridge, rode with me into the Mallee, accompanied by one of his native stockmen, who, on our approaching the edge of one of the plains, at once pointed out the tree.'

After cutting a yam stick about 5–6 feet (150–180 cm) long and tracing the roots discernible by a small crack on the soil surface, the root was prised out of the ground until about 15–20 feet (4.5–6 m) of root had been laid bare. After breaking the roots into 3–4 feet (90–120 cm) segments and stripping off the bark from the lower end of each, they were reared against the tree with their lower ends placed in a collecting pannikin.

'It grows upward of twenty feet (6 m) high, and scarcely differs in appearance from those around to the eye of a stranger, but easily to be detected on the brownish tinge of its leaves.' (Cairns 1858)

1860, North of Euston, NSW

'On the sandy soil at the edge of the Mallee, we saw the water-yielding *Hakea*, which was to me quite new. One fine tree seemed so full of water that the outer bark, to the height of a foot from the ground, seemed quite saturated.'

While resting our horses at Mr Ross's, we had also leisure to experiment on the water-yielding *Hakea*. The first root, about half an inch (1.3 cm) in diameter, and six or eight feet (1.8–2.4 m) long, yielded, quickly and in large drops, about a wine glassful of really excellent water.' (Morton, W.L. 1861, pp. 128, 132)

1860–1938

'Trekking along the old pad, a discussion arose on the theory that, as a last resort, sufficient water can be found in the roots of trees to maintain life. Wells was of the opinion that the theory was good, but impractical in reality. At last, to settle the question, a root was grubbed up from a bloodwood as the most promising tree upon which to make the test. About half a wine glassful of fluid was obtained, whilst they drank a much greater quantity from the kegs to enable them to continue the work of testing!'

'It was finally declared a theory only, impractical as far as the trees in this desert were concerned. In mallee country further south it was said that Aborigines did obtain water from the mallee trees, but a white man would need an axe to obtain the roots and the exertion of delving would cause the transpiration of more moisture from his body than he could possibly derive from the tree.' (Steele & Steele 1978, p. 77)

1861

'...my brother and I had gone in for the roots of the hakiea (*sic*), or prickly mallee. It being virgin ground, untrodden by sheep or cattle, it was easily pulled up in lengths of 20 or 30 yards (18–27 m). We cut it in pieces of about a foot and placed it upright in a tart pot and billy and soon got a good drink each, and with that had to make shift until we reached Narr.'

'The boys left me, and that was all I saw of them during my stay at Tolorgawank, but I often came across their camps, and the heaps of havea (*sic*) roots was something astonishing. You could see them piled up like small hay stacks at all their camps; in the summer time they had little else to depend on.' (Everard 1883, pp. 17–18)

1872, Central Australia

'A white man would die of thirst while digging and fooling around trying to get the water he might know was preserved by the tree, but not for him; while an aboriginal, upon the other hand, coming to a mallee-tree, after perhaps travelling miles through them without noticing one, will suddenly make an exclamation, look at a tree, go perhaps ten or twelve feet away, and begin to dig.'

'In a foot or so he comes upon a root, which he shakes upwards, gradually getting more and more of it out of the ground, till he comes to the foot of the tree; he then breaks it off, and has a root perhaps fifteen feet long—this, by the way, is an extreme length. He then breaks the root into sections about a foot long, ties them into bundles, and stands them up on end in a receptacle, when they drain out a quantity of beautifully sweet, pure water. A very long root such as I have mentioned might give nearly a bucketful of water...'

'There are a few other trees of different kinds that water is also got from, as I have known it obtained from the mulga, acacia trees, and from some casuarina trees; it depends upon the region they are in, as to what trees give the most if any water...' (Giles (1889, vol. I, p.45)

1876, Central Australia

'Water is also procured from the hollow eucalyptus trees; also very commonly from the roots of trees. They select the proper roots, break them in pieces and stand them on end in a wooden dish, which catches all the water that is in them. By this means they often travel far away from anypermanent water.' (Forrest 1876, p. 320)

1883, Between the Lachlan and Darling rivers, NSW

Grows chiefly on sandy or light loamy soil throwing out numerous lateral roots 6–12 inches (15–30 cm) below the soil surface.

Roots located by jabbing spear or sharpened stick into the ground, 6–8 feet (180–240 cm) from base. The root is exposed by removing the covering soil with a wooden shovel for 20–30 feet (6–9 m) before cutting into 1.5–2 foot (45–60 cm) lengths and standing on end in a receptacle. After draining, the last of the water is expelled by the Aborigine blowing down each root segment. 'The roots chosen are—with the bark on—about the size of a man's wrist, ... The water is beautifully clear, cool, and free from any unpleasant taste or smell.' (Bennett (1883, p. 215)

1888

'We are indebted to the aboriginals for a method of obtaining water, and that from a source in which we should perhaps least look for it. This simple method, which had best be given in the words of those who have had much intercourse with the blacks, is now given, and no adult in Australia should be ignorant of it.'

'There is no doubt that a knowledge of this method of obtaining water would have been the means of saving the lives of some people who have suffered one of the most terrible of all deaths—death from thirst.' (Maiden 1888, pp. 481–2)

1888–89, North of Queen Victoria Spring, WA

'We were now in the desert proper for several days, and in a depression round some stunted trees we could see where natives obtained water out of the roots, as broken roots were strewn about.'

'They showed me how to look for the water in the mallee root. Look for a likely tree, one with dark green leaves and without any dead limbs, or look for the fine little cracks in the surrounding ground. By pulling the roots up, and then breaking them into pieces and either sucking, or standing them up in a vessel or dish, the water percolates out. I have drunk the water and made tea out of it. It has a slight eucalyptus flavour. I have seen many places even in the desert where the blacks had resorted to this water supply, the ground being strewn with pieces of roots.' (Luck 1988, pp. 125, 130)

1889, Northwest Victoria

'The roots of this tree grow near the surface, and run laterally, sometimes for thirty of fort feet, without any appreciable differences in diameter.'

'These roots they tear up and break into short lengths, which pieces are placed on end in an improvised *coolamen*. In half-an-hour the roots will be drained quite dry. From half-a-dozen such roots—that is, twenty or thirty feet long—as much as three or four gallons of water will be procured.'

'The water is very nice and cool, having the very faintest sub-acid flavour, which makes it a most delicious, as well as refreshing beveridge for hot and thirsty travellers.' (Beveridge (1889, pp. 27–8)

1891,Victoria Desert, WA

Unknown—'...It requires, however, the knowledge of an aboriginal to hit upon the proper tree, for which there are probably some outward signs only known to them, because my own efforts led me only accidentally to a root holding water, after trying a good many before without obtaining a drop.'

'The supply from such sources is scarcely better than that obtained from the roots of the mallee. This last-mentioned supply is no doubt in many places often resorted to, and when the proper kind of root is found yields a splendid, clear, and cool water, that at times drips rapidly from the broken roots when they are held vertically.'

'The 'wanna' and the 'wera' are the constantly accompanying implements of the blacks of the interior, and are frequently used during the whole day for the purpose of digging, either for water or food. The wanna is used for loosening the soil, or as a lever

when roots or stones require lifting, and with the wera the loosened stuff is scooped up.' (Helms (1896, p. 254)

1893

'[The] only water they get all through the summer is drained from red mallee roots, piles of which may be seen in some parts of the scrub...' (*South Australian Register* 1893)

1894, North of Queen Victoria Spring, WA

'...the quantity of mallee root heaps, suggested the possibility that the natives could obtain from them sufficient moisture to live upon. I think now that this is most unlikely, and that the roots are only resorted to when travelling or in time of great need.' (Carnegie 1898, p. 43)

1895

'Trees growing in hollows between ridges will have greater abundance of water than those growing on the ridge tops.'

'A native goes to a water-tree, and tries the ground at from four feet to five feet (1.2–1.5 m) from the stem; or, if guided by 'bulge' or 'crack', finds the root at once...Then dropping spear or stick he grasps the root with both hands, and straddling its bed, shakes, and pulls up the root to its points.'

'The red mallee of the west coast of South Australia is very porous, and the water gushes out at once when set on end. On the Scotia Blocks (S.W.) of New South Wales the natives make high stacks (four feet or so) of the drained roots; why is not evident.' (Magarey 1895, pp. 648–51)

1903, in proximity of Camp 39 near western end of the Mann Ranges, NT

'...triodia sandhills, with occasional currajong and clumps of mallee. I noticed that the currajongs existing in these sandhills are frequently, if not invariably, surrounded by a ring of fresh mallee...Is this phenomenon a consequence of the noted storage capacity for water of the currajong?'

'The young shoots of the currajong are chewed as a substitute for water by travelling desert tribes, and water can be obtained from the cut tap-root by setting fire to the foliage to expel it.' (Basedow 1915, p.126).

1904, Southwest NSW

'Those selected are generally from 1 to 3 inches in diameter, and are easily dug up, as in many cases they extend laterally as far as 10 feet withouy varying much in thickness, and are not more than 9 or 10 inches below the surface. A good root, say 10 feet long and $2^{1/2}$ inches in diameter, would yield a quart of water, which, though not very palatable to those unaccustomed to it, is liked by those who have used it for a long time.'

'There is a large extent of country, without any permanent surface water, between the Darling, Murray, and Murrumbidgee Rivers. This was occupied by the Berriait tribe, who, when the surface water failed them, obtained a supply from the Mallee, a species of Eucalypt, and from one of the Hakeas. At times of drought they were forced to go to the rivers for water...' (Howitt 1904, p. 51)

1911, Near Skeleton Soak, northwest Victoria

A Mr Wiltshire and companion J. Cornell nearly perished while out tracking a lost horse. They '..dug up the roots of the mallee, which for a time allayed the pangs of thirst.' (*Pinnaroo and Border Times*, 8 December 1911)

1914–15, Northwest Victoria

'Water, almost pure, can be extracted from the roots of one species of the Mallee growing in certain situations: about a quart will drain from two or three roots perhaps in half-an-hour.' (Kenyon 1914–15, p. 43)

1919, Ooldea, SA

'...water bush (growing round soak, native name wilbala), Ngabbari (mallee), Ngalda (mallee with water-bearing roots), and one or two species of acacia, are scattered widely over the district; but most of the largest trees have been cut down to supply the engines and workmen with firewood.'

'A mallee tree here and there also shows itself above the mulga and sandalwood, but there are very few mallee trees left in the vicinity of Ooldea.' (Bates 1919, pp. 76, 78)

1924

'Needle bush (*Hakea leucoptera*), Red Mallee (*Eucalyptus oleosa*) and even the Box (*E. microtheca*) afford another means of procuring water. Their roots are dug up, cut into short lengths, and placed to drain in a *pirrha* or wooden bowl.'

'Quite a quantity of fluid is yielded that has been stored up by these plants. It is not very nice to the taste, but in that dry sandy desert any fluid that is drinkable is good.' (Horne & Aiston 1924, p. 50)

1926, Great Australian Bight, SA

'Very soon we emerged from the scrub on to an open plain, almost circular in shape, about 10 acres (4 ha) in area, level as a bowling green, covered with tall dry grass which undulated in the breeze like a golden wheat field, and with very large mallee, as is usually the case, along the edges...Tommy seized his tomahawk, I took the quart pot, and we started our walk round the edge of the timber, when, after proceeding a few chains, Tommy stopped, and pointing to a mallee, said: 'That feller.'

'Tommy went half a dozen yards (5.5 m) from the trunk into the open ground, and, driving his tomahawk into the ground, started a sort of costeen scratch with the six yards as radius. Presently he struck a root, cleared the earth away from it a bit, chopped it across, and then taking one end in both hands stripped it up along the surface away from the tree, and soon had about six feet (1.8 m) of root, a finger in thickness, exposed. By similar prospecting we soon got a sufficient supply of roots, and then proceeded to break it up into lengths of about eight inches (20 cm). These were carefully peeled and stood up in the quart (1 litre) pot to drain off the moisture, which exuded plentifully on fracture; the operation was slow, but I assisted by blowing through cane, and finally the quart pot was nearly full of water.'

'The tree was a fine one, about 15 feet (4.5 m) in height, the trunk and main stems were quite clear of twigs or branches, and were covered with snowy white bark. The foliage formed an umbrella-shaped top to the tree, and had a very bushy appearance, the leaves seemed shorter and broader than those of the ordinary mallee, were of a vivid green, and had a bright shiny look. It is hard to describe this tree, because I can think of no tame tree, so to speak, with which I can compare it.' (Gee 1926, pp. 61–3)

1926, Ooldea, SA

E. oleosa reported as water mallee at Ooldea; *E. incrassata* and *E. dumosa* as water mallees in desert country. (Black 1926)

1928, South of Alice Springs in vicinity of hill country on 'Angas Downs' or 'Curtin Springs'

'Among a clump of big scrub-mallee growing in a dip below the ridges, Tuck halted the train and waited for me to come up. 'Water-bearing mallees,' he said nonchalantly. 'See 'em?'

'No, that I can't. Where?'

'Why here ... all round ... lots of 'em ... We'll hoosh down and have a look at 'em.'

'The trees I now noticed, had roots with sections growing alternately above and below the ground, and all the roots were long and twining. With Tuck wielding the shovel a root was soon exposed and torn from the ground. It was thirty feet (9 m) long and no thicker than a man's wrist ... it is in reality an underground stem or rhizome. In each rhizome, which often contains a length of fifty feet (15 m) or more, is enough water to sustain a man for a day.'

'... when hung vertically, the 'roots' discharge their water freely and would soon empty, the flow may easily be checked by holding the 'root' in a horizontal position ... Thus Nature has provided the aboriginal with a natural waterbag.' (Russell 1934, pp. 100–2)

1937, Scotia region, southwest NSW

'It is said that there are still to be found out there the relics of Nanya's occupation, and the piles of long-withered mallee roots from which, stripping the bark and draining patiently, for thirty years his people obtained their supplies of water in many cruel droughts.'

Nanya was the last full-blooded chief of the region, ' a Cuthero man of the country on the verge of the Darling', who eluded police for over thirty years before he and his remaining tribal members finally moved to Lake Victoria. (Hill 1937, pp. 276–8)

1939, North of Ooldea, SA

Root water seen in most quantity in superficial radiating roots of *Eucalyptus transcontinentalis* ['perhaps only a variety of *Eucalyptus oleosa*'] radiating from the butt for 30–40 feet (9–12 m).

Usually only 1 inch (2.5 cm) below the surface of sandy soil, they could be readily pulled up in lengths of many feet. 'They are relatively brittle and on examination consist almost entirely within the layer of bark of closely set tubes just visible to the naked eye'.

'Broken into lengths and held vertically aloft over the mouth or on end in a receptacle, water drips freely, sometimes almost in a stream, whilst by blowing at the upper end it gushes and bubbles forth from below.' (Cleland 1939, pp.8–9)

1943, Victorian Mallee

'Nature, as if to make amends for the scarcity of water, provided a perennial supply in the roots of several trees.'

'Many explorers, including Major Mitchell, record the methods by which water—'beautifully clear, cool and free from unpleasant taste or smell'—was obtained. The roots were dug from the ground, cut into foot billets and sucked as in the act of smoking, or allowed to drain into skin water-bags.' (Morris 1943, p. 167)

1944, Ooldea, SA

'Some of the bush natives came in this week with stories of great hardships even for natives, who are generally very tough. They returned after a nice rain, thinking the rock holes to the north [of Ooldea] would be full, but they found no water and had to subsist

for five days on water obtained in small quantities from the roots of a certain type of mallee.' (Turner 1950, p. 113. This account was taken originally from the *United Aborigines' Messenger,* July 1944).

1953, 'The waterless Kochia country, contiguous with the boundary fence between New South Wales and South Australia.'

'They lived by spearing the scrub kangaroo and by hunting lizards and digging out the eggs of the termites; water, such as they needed—which wasn't much, for the blackfellow never 'soaks' like the white man—they usually obtained from the roots of the red mallee and needlewood trees.' (Russell 1953, p. 61)

1954

Description of root-water collection. (Charnley 1954)

1963, Neal Junction, ENE of Laverton, WA

'In dry seasons when the water holes dried up they lived from the moisture sucked from the roots of the mallee-like water tree.' (Allan 1964, p. 34)

1966

'Beginning in the south, there are considerable stretches of mallee scrub composed of low-growing many-stemmed species of *Eucalyptus* (*E. dumosa* A. Carr., *E. oleosa* F.v.M., etc), as in Eyre Peninsula and near the Murray. Many of the mallees have surface-spreading water-bearing roots.'

'The long superficial and almost horizontal roots of a number of species of mallee (Eucalypts) yield considerable quantities of very good water. These roots can be readily detected and then exposed with a yam stick, and sections pulled and stood on end in a wooden vessel and the water collected. A piece of such a root held erect may drip water almost in a continuous stream of drops.' (Cleland (1966, pp. 114, 139)

1966, Murray mallee, southwest NSW

'Armed with an axe or a tomahawk, anyone lost in the mallee, who knew the water-bearing type of tree, could get a drink by draining short lengths of the roots into the dented crown of his hat—provided, as Andrew remarked grimly, that he was not yet on the edge of delirium and had the mental stamina to endure the slow process.' (Broughton 1966, pp. 98–9)

1966–69, Victorian Mallee

'Water was also obtained from the roots of some of the eucalypts, which the natives called *Weir-mallee.* They are recognisable by the comparative density of the foliage.'

'These trees have long horizontal roots only a few inches below the surface of the soil. After digging them up the natives broke them into short lengths, and up-ended them, making sure that the end farthest away from the tree was at the top. Good clear water soon dripped out from them, a root of 15 to 20 ft (4.6–6.1 m) yielding between a pint and a quart (0.6–1.1 L)'. (Massola 1966, p. 270; 1969, p.73)

1969, Scotia mallee, NSW

'In 1923 the first artesian flow in the south spilled out over country where the Nanya tribe had once kept themselves alive by tapping the meagre reservoirs stored in the roots of mallee trees.' (Hardy 1969, p. 182)

1972, North of Mt Crombie towards Mt Harriet, NT

The mallee belts between the sandhills continued for about four miles, with a few desert kurrajong trees (*Brachychiton gregorii*) yielding food seeds and edible flowers and roots.'

'The factors, in general order of importance, that determine choice of campsites by the Pitjandjara can thus be summarised as follows:
1. The presence of water in spring, soak, well, rockhole, or (least attractive) tree roots.'

'Five miles out [northern piedmont of Mt Crombie] mallees (*Eucalyptus* spp.) began to appear and several other species of *Acacia*. The mallee roots yield water...'

'Men also wave *Eucalyptus oleosa*, water mallee branches, in the air to fetch cold, rain-laden southerly winds.' (Tindale 1972, pp. 233, 236, 244)

1972, Southern Kimberley, WA

'In addition, emergency water can be obtained, for example, from some trees and/or their roots or from underground deposits of coagulated frogs.' (Berndt 1972, p. 179)

1973, Between Lah and Jeparit, Victoria

'Old local people speak of soaks and of water in holes in red sandstone outcrops scattered here and there through that country; and these must have been known to the Aborigines and have supplemented that which they carried with them in skin bags or obtained from Mallee roots.' (Massola 1973, p. 130)

1974

'Other distortions of the symmetrical patterns [of tribal lands] may come when the people of a tribe are adapted to particular ranges of food or special water-using habits. Thus we notice that the Kokata tribal territory [running westward from Woomera] is long drawn out along the belt of mallee forested country in which they find their water-bearing roots...'

'In general open mallee plains have few distinguishing marks, a whole area many miles across may be useful only insofar as it provides a vast series of temporary homes. The trees yield water from their roots but it is a wasting supply, since once used the locality cannot be used again.'

'The Ngarkat tribe, which inhabits the mallee scrub country south and east of the Murray River, is an example of a nomadic people without a fixed nomenclature for its homes. The Pindiini tribe may be cited as another group where a different grove of mallee trees has to be chosen for each day's shifting camp. They also live in a land without many names, except for a few places providing more stable conditions for habitation, and these become key clan places where their ancestral beings reside.' (Tindale 1974, p.40)

1975, Wyperfeld National Park

'Hakea or mallee gum roots, chopped into foot lengths and allowed to drain into a bark dish, provided good clear water.' (Allan 1975, p.4)

1978

Water, apart from rock-holes and soakages, is sometimes obtained from '...a few unusual sources such as the forks of large gum trees, the roots of certain trees (which are dug out, cut into foot-long (0.3 m) pieces, and drained into wooden dishes), and even dew.' (Tonkinson 1978, p. 23)

1989, Scotia mallee, NSW

'Water was obtained from the roots of red mallee or waterbush, and the women dug white ants or ants eggs out of the earth, shaking them expertly on a coolamon of bark, which they put on the hot ashes to roast for a while.' (Withers 1989, p. 124)