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Report on Australian Flora Foundation grant "The status of the waddi tree (*Acacia peuce*) in Queensland"

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Introduction

This project set itself the task of evaluating the status of the rare desert tree *Acacia peuce* in Queensland. In the event, resource limitations required a focus on the stand at Boulia. The stand at Birdsville remains to be fully investigated. The project has triggered a significant amount of extra research into tree physiology, phenology, seeding survival, growth rates, patterns of senescence and effects of grazing on tree health. The work was supported by additional funds from the Australia Pacific Science Foundation and James Cook University. Work at Boulia is continuing.

The state of the stand

In 1980 Ed Deveson prepared a map of the known distribution of *Acacia peuce* at Boulia and Birdsville. He estimated that the total population in the Boulia district may exceed of 100,000 trees with 25,000-30,000 individuals in the main stand that grows on Montague Downs Station, Mudgecca Station and Marion Downs Station. Local accounts suggest the stand has thickened substantially since the flooding rains of the 1973/74 wet season and we have no reason to doubt this view.

By way of an analysis of *Google Earth* imagery, Arnaud Gracher was able to identify individual *A. peuce* and assign them to adult or juvenile growth forms. The method proved to be unworkably labour intensive but he was able to digitise about 66% of the main stand and count 4890 adult trees and 46187 juveniles. An estimated 20,000 further trees in the stand were not digitised.

There was a slight tendency for younger trees to be in the north of the stand suggestive of a degree of northward expansion onto Goodwood Station.

A plot based analysis of tree density and size supports the remotely sensed data. Tree densities are comparable to those reported by Deveson however the size distribution reflects 30 years of extra growth. We conclude that a substantial number of trees germinated in the 1973/1974 season survived, and are members of the living cohort. There are no areas of extensive dieback of *Acacia peuce* in the Boulia district and we believe that Deveson's estimate of 100,000 trees occurring in the Boulia district is at the upper end of the potential population but remains essentially valid.

Acacia peuce flowers sporadically throughout the year. Pods can be found on a few trees at any time. Fresh seed viability exceeds 90 percent and no particular treatment is required for germination. The high rate of viability of seed might be taken to argue against any proposition that low seed production reflects inbreeding and reduced genetic fitness in a declining species. Flowering tends to be more common in the period between October to March when rain is less unlikely than in other seasons however small numbers of seed pods are found on threes throughout the year.

Waddi tree bud and flower.

Pollination is likely to be insect mediated as the flowers and buds attract flies and other flying creatures and, in keeping with all *Acacia* species, the pollen are shed as polyads which are too heavy and compact to blow far in the wind. There appears to be gene flow within stands however many pods contain aborted or unviable seed and the efficiency of pollen transfer remains open to debate. It is extremely unlikely that pollen are able to bridge the gaps between stands.

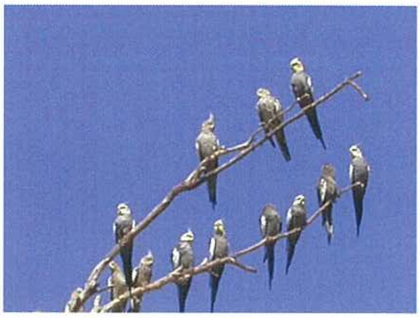
Graziers near Boulia suggest that *Acacia peuce s*eeds can be dispersed along drainage lines and this is a proposition worth considering. It is at least possible that some of the trees at Birdsville were derived – in the distant past - from the Boulia stand by seed washed down rivers during flood times. The fate of intervening populations, and the mechanisms by which colonisers spread (up-wind) from the channels to the current sites occupied by waddi trees, remain a mystery. There is no chance at all that trees in the Mac Clarke Reserve owe their occurrence to fluvial processes, except at the smallest of within-stand scales, as there is no co-ordinated drainage in the vicinity, ancient or recent, and the nearest river system, the Finke, drains a waddi-free catchment.

Seeds lack eliasomes or other structures indicative of bird, insect or mammal vectored dispersal. There is a distinct seed shadow effect around pod bearing trees, consistent with suggestions that seeds are dispersed by the wind blowing pods about, with the pods opening on the ground to liberate the contained seed. There is no soil seed store. Seedlings germinated after good rains in 2008 were found in quadrats during 2009, 2010 and 2011. A second germination event occurred in 2010 but many were showing signs of stress when re-visited this year.

Recently germinated seedling

We are unable to judge what proportion of the missing seedlings were browsed, however it is clear from pot trials and excavation of a seedling root system that *Acacia peuce* sends down a rapidly growing tap root in pursuit of soil moisture. The best seedling survival in our quadrats is on sandy soils, which allow the tap root to grow rapidly, even though the soil moisture front also recedes rapidly. Moisture stress is the most likely reason for seedling death, except in the sacrificial zone around water points where trampling and browsing are severe threats.

At present the only vertebrate seed predators known to affect the waddi tree are galahs and cockatiels whilst cattle will browse green pods.



Cockatiels appear fond of waddi tree seed and will set about extracting it from pods by chewing around the margins of the swelling which shows where the seed lies in the leathery legume, leaving the distinctive lesions visible on the image to the right.

It would be most surprising if the native rats, such as *Rattus villosissimus*, which live in waddi tree communities did not take advantage of seed and pods which fall to earth within their reach.

Waddi tree seeds lying loose on the soil surface at Boulia in November 2007

As there is no soil seed store, we believe that *Acacia peuce* recruits opportunistically. There are always fresh seed available for germination although some seasons exhibit more intense flowering and seed production than others. Successful recruitment may occur following any significant rain event but massed recruitment is probably associated with the exceptional conditions such as those of 1973/74. We do not believe that recruitment is limiting in the Boulia district. In 2010 we found that *A. peuce* is able to reproduce vegetatively. It is not yet clear to what extent vegetative reproduction contributes to the stand.

Longevity

Acacia peuce is often considered to be an exceptionally long-lived tree. Estimates based on girth increments and gut feelings have lead to estimates that some of the larger trees might be as much as 500 years of age. A number of stumps of trees cut for fence building were subjected to accelerator mass spectroscopy (AMS) radiocarbon dating. Most samples submitted for dating came from the centre of the biggest available tree stumps and therefore reflect the age of the tree reasonably closely. Stumps cut by chainsaws were used in order to avoid dating trees that died years before and have lain on the ground for some indeterminate number of decades – or perhaps, centuries. Results are presented in Table 1.

Table 1 – AMS radiocarbon dates from *Acacia peuce* stumps

SAMPLE	LAB CODE	δ13C	% Modern	14C yrs BP
Montague 1	WK 24295	-23.9	98.7 +/- 0.2	109 +/-30
Montague 3	WK 24296	-22.9	98.4 +/- 0.2	133 +/- 30
Montague 6	WK 24297	-23.1	98.3 +/- 0.2	134 +/- 30
Roseberth 1	WK 20778	-22.7	98.3 +/- 0.4	136 +/- 29
Roseberth 2	WK 20779	-21.3	97.7 +/- 0.4	185 +/- 29
Roseberth 3	WK 20780	-24.6	97.6 +/- 0.4	197 +/- 29
Roseberth 4	WK 20781	-23.4	97.5 +/- 0.4	205 +/- 29
Roseberth 5	WK 20782	-24.3	98.2 +/- 0.4	145 +/- 30
Mac Clarke 4	WK 20783	-23.1	97.5 +/- 0.4	206 +/- 30
Mac Clarke 1 (sapwood)	OZJ 710	-19.5	121.26 +/- 0.51	Modern
Mac Clarke 1b (trunk centre)	OZJ 711	-19.8	98.17 +/- 0.5	150 +/- 45
Mac Clarke 2 (trunk centre)	OZJ 712	-20.6	98.17 +/- 0.48	150 +/- 40
Mac Clarke 2b (sapwood)	OZJ 713	-20.4	98.91 +/- 0.45	90 +/- 40
Mac Clarke 3 (sapwood)	OZJ 714	-19.5	97.59 +/- 0.47	195 +/- 40
Mac Clarke 3b (trunk centre)	OZJ 715	-18.7	94.82 +/- 0.48	425 +/- 45

The results are surprising but before commenting on them, it is worth noting that the raw ages do not mean a great deal. This is because there are a number of corrections that must be made before the radiocarbon age (yrs BP) can be converted into calendar years. The precision with which this calibration can be made differs through time and the ages recorded for *Acacia peuce* in this suite of samples happens to be one where calibration is very imprecise and calendar ages are, therefore unreliable. Note that radiocarbon ages are quoted with an error term of 1 standard deviation (eg 205 +/- 29 BP) which reflects the precision of measurement of radiocarbon abundance in the sample. Effectively it means that there is a 66 percent chance that the true age lies between the bounds of the error.

Samples 1 to 5 came from trees growing on Roseberth Station near Birdsville; the others come from the Mac Clarke (*Acacia peuce*) Conservation Reserve about 300 km south of Alice Springs, on the western side of the Simpson Desert.

Roseberth No 1 (WK 20778) is a spectacularly large individual (dbh 44cm) felled in 1973 to use as a strainer post. This means that the actual age of the tree is about 34 years younger than the apparent radiocarbon age. To allow for the radiocarbon year zero being set at 1950 A. D., we need to add 23 years to the radiocarbon age. This would make it about 120 years old when cut. The wood was in excellent condition, despite being on the ground for 33 years.

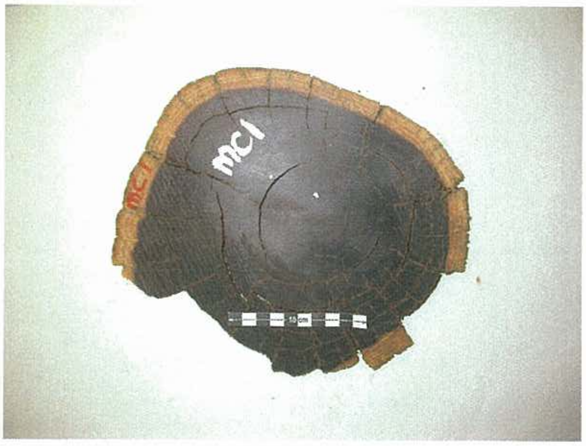
Roseberth No 1

Roseberth No.2 is a gnarled and venerable specimen that appears to have been cut many years ago and has defeated the best efforts of generations of axe wielding tourists. It too has impressive girth and is comparable to the larger individuals in the Birdsville stand.

Roseberth No 2 in its natural habitat

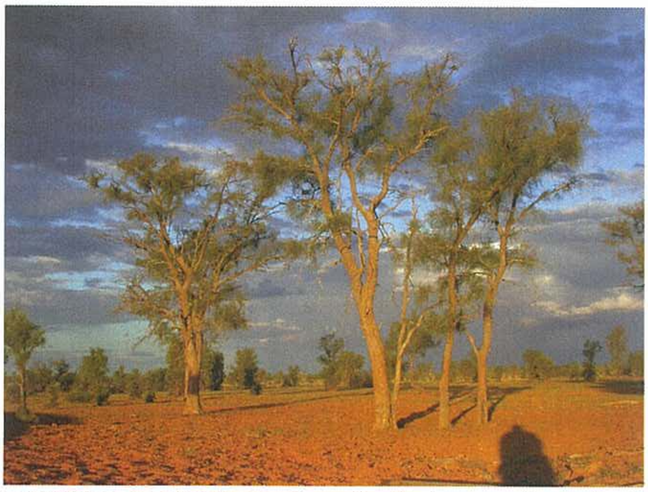
Mac Clarke No. 1 is one of more than 100 trees killed by a lightning-started fire in 1976 and so you need to subtract about 30 years from the apparent radiocarbon age to get an idea of the age of the tree and make the same correction as for the other dates to allow for the starting of the radiocarbon timescale at 1950 A. D. This would suggest the tree to be about 200 years old when it was killed.

Dead waddi trees near Rieks Dam on Old Andado Station, Northern Territory.
These trees were killed in the1976 fire



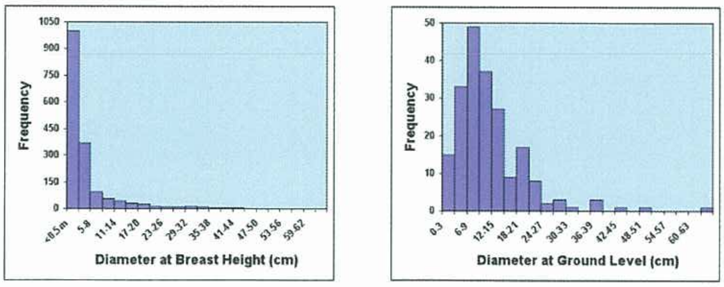
The Mac Clarke No 1 cross section

The dates suggest that even the larger waddi trees are significantly younger than anticipated. As the trees sampled were killed rather than died, they do not, in and of themselves, say how long a waddi may live but as their sizes are comparable to the biggest living trees and the few trees that are larger are almost always showing signs of advanced senescence the hypothesis that waddis compensate for sporadic reproduction by extraordinarily long lives is not sustained.



Large, apparently senescing waddi trees near Mudgeacca bore. Smaller trees nearby are in robust good health, suggesting that stock activity is not the cause of crown dieback

The majority of mature stems were between 20.1and 25.0 cm diameter over bark (d.o.b.) in 1982 but there were also many small stems (0-5cm d.o.b.) whose presence was attributed to regeneration following the flood years of 1973-1974. More recent data show persistence of a large number of smaller trees.



Stem size frequencies at Boulia in 2007.

In 1980 Ed Deveson attempted to obtain conventional radiocarbon dates from a 40 cm dbh tree from Boulia and found a radiocarbon age of 110+/- 20 BP which, when calibrated for atmospheric variations in ^{14}C equates to about 140 +/- BP. Ages estimated from ring counts from the tree Deveson dated ranged between 127 and 165 "years". Deveson noted that the radiocarbon age from pure cellulose was significantly younger than that from whole wood and was concerned that there may have been contamination of the cellulose extract and that the whole wood age is the best estimate. Deveson also suggests that there may be radial transport of carbon compounds into the trunk and that wood storage of carbohydrate to fuel growth may lead to anomalously young ages from stem materials. This seems extremely unlikely given the wood density, thinness of sapwood and absence of medullary rays in wood sections we examined. AMS radiocarbon dating suggests that the largest cohort of *Acacia peuce* trees are approximately 200 years old. Older trees no doubt exist however the state of senescence of large living trees suggests they are unlikely to live to the 400 – 600 years assumed or estimated.

There are two anomalously old dates presented in Table 1. These are from trees Mac Clarke 2 and Mac Clarke 3. Each of those fallen stems had been burned at the base of the trunk.


Trunks of waddi trees that died well before the 1976 fire in the Mac Clarke Reserve.
The tree on the left died some ~90 ^{14}C years ago, the one on the right, ~195 ^{14}C years ago

Although it is possible that they had been burned through and fallen in 1976, it seemed equally likely that they were already dead and on the ground when the fire passed through. To test this, I collected samples from the centre of the trunk, as per the rest of the trees but also took wood from the outermost part of the sap wood. One of the trees died about 90 ^{14}C years ago and the other 195 ^{14}C years ago. The wood of both trees is in remarkable condition and it is clear that waddi tree trunks can remain in the landscape storing carbon and providing habitat for a very long time. This is one of the very few instances where the length of time that coarse woody debris can survive has been measured and is clearly a minimum figure as logs in all stages of decomposition occur through waddi tree stands.

Fire and the waddi tree

Waddi trees are sensitive to fire. The death of trees after a fire in the Mac Clarke Reserve in 1976 was attributed to passage of a relatively high intensity fire burning grassy fuels, the product of a wet summer the in previous year. Most plants survive fire reasonably well courtesy of all sorts of adaptations, many of them structural. A key role is performed by the bark, which insulates the heat sensitive cambial tissue and protects it from damage. The thicker the bark, the better the insulation. The effectiveness of bark as an insulator interacts with the residence time of the fire in the vicinity of the tree. Burn-out time dictates the time over which the heat pulse from the fire builds, passes into the bark and dissipates as the fire passes. With grassy fuels, the burnout time is short so that even if the fire is intense, temperature builds and declines rapidly. Unless there is an accumulation of fuel, such as leaf litter, around the base of the tree the fire passes in a few minutes.

In 1976 lightning ignited a fire which killed about a hundred waddi trees near Rieks Dam. There are no data that allow detailed reconstruction of the fire but a few observations are pertinent. First, the fuel load is unlikely to have been more than about 3 tonnes/ha^{-1}. Under more or less average conditions (relative humidity 10%, air temperature 35°C, wind 20 kph and fuel fully cured) a rate of spread of ~5kph might be expected. This would generate fire intensities of ~7500kW/m^{-1}. Under normal circumstances, woody plants subjected to such a fire would not fare too badly. There is rarely much litter accumulation under waddi trees so it would be reasonable to infer that the fire passed quickly. Waddi tree bark is thick (~ 2 cm or so according to measurements made by Joe Holtum) and persistent; I expect it to be an effective insulator, and yet the trees still died.

Stems killed in the Rieks Dam fire average 13.1 cm d.b.h. (compared with average of 24.9 cm for trees on the un-burned Mac Clarke Reserve hill site). These are relatively small trees and many of similar size still sport the dense fringe of spiny foliage characteristic of the juvenile growth form. This foliage, which includes live tissue and a mass of dead grey material, is very flammable and would burn for a great deal longer than grass. If burning it would pose a challenge to the survivability of the tree.

The juvenile growth form of the waddi tree produces abundant fuel (left and centre), unlike the mature form seen on the right.

Young foliage is flammable – it would do a tree no good at all if it caught alight.

The skirt, if it existed on the Rieks Dam trees in 1976, would also act as ladder fuel, carrying fire into the tops of the tree where bark is thinner and apical buds are exposed. It is likely that large trees with the adult growth form are less sensitive to burning than are juveniles.

Management fires are not a threat to waddi trees in Queensland but wild fire consuming the accumulation of grass in good seasons may pose a stand-scale threat. Grazing practice in waddi country depends on rapid adjustment of stock numbers to seasonal conditions and at times when grass growth is favoured, stock numbers are increased rapidly to profit from the feed. Grazing pressure rapidly reduces the fuel load and breaks fuel continuity, thereby reducing the risks posed by unplanned fire.

Grazing and *Acacia peuce*

All stands of *Acacia peuce* in Queensland are on pastoral leases and in the Northern Territory, grazing is regarded as a potential threat to the species. Around Boulia there are clear indications that grazing by livestock affects *Acacia peuce* but we believe the effects to be of limited significance.

Inspection of scats indicates that waddi trees are browsed by cattle, macropods and camels. The effects of such browsing are most obvious in the vicinity of water points, where juvenile waddi plants frequently appear to have a bonsai-like form characterized by dense branching, rounded shape and an interlocking armature of rigid, pungent tipped phyllodes. Bowland and Heywood (2002) believe such plants may be up to 50 years old and we have found no indication to gainsay that or that when browsing continues, the plants can develop normally. The morphology of *Acacia peuce* at different growth stages is strongly suggestive of adaptation to vertebrate browsing pressure, probably from the now extinct Pleistocene megafauna and we believe that if browsing is a risk to the species, it is to recently emerged seedlings rather than to juvenile or mature plants.

Many trees in the vicinity of water points are large and showing signs of senescence, though most are likely to live for decades yet. When they die, they are unlikely to be replaced, leaving water points more open than they are today. A program of reticulation of water to remote areas of paddocks is underway as a means of distributing grazing pressure. We are unable to comment on the likely effects of this change on waddi trees previously outside the radius of grazing from water points.

Apart from mechanical damage to stems and foliage, grazing may have severe effects on the root environment. Trampling in the vicinity of water points is severe. We originally believed that the roots of *A. peuce* were too deeply buried to be much affected by surface trampling but it is now clear that the trees also produce long surface roots whose function is unknown. These roots occur close enough to the soil surface to be affected by trampling however we have yet to examine either the impacts or implications of disturbance.

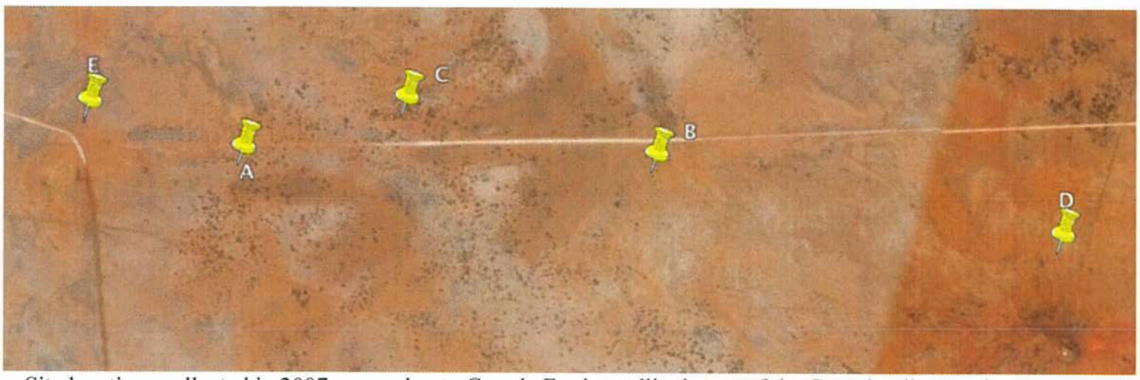
Sucker emerging from shallow horizontal root on the edge of a stock tank on Mudgeacca Station. Note the eroded surface, shallow depth of the root and the 90° bend where the root changes from horizontal to vertical orientation

As noted above, browsing almost removes a proportion of newly germinated seedlings but we cannot quantify the effect. Graziers suggest that the removal of sheep from the region in the early 1980s contributed to greater seedling survivability and thickening up of the Boulia stand. If true, this suggests that stand dynamics can be affected by grazing pressure.

We conclude that the waddi tree stand at Boulia is disadvantaged by grazing pressure through browsing, seedling loss and soil disturbance. None of these factors appears to be placing the stand at risk and it is likely that grazing reduces the risks posed by wild fire – on balance, grazing and waddi trees appear to be able co-exist at Boulia, a circumstance which does not prevail elsewhere within the waddi tree range.

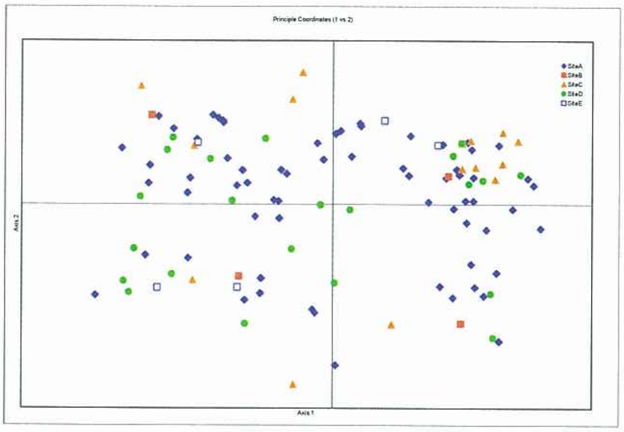
Genetic diversity of *Acacia peuce* at Boulia

In 2007 a study of the genetic diversity using DNA fingerprinting was carried out by students form JCU. The results were very revealing. Using DNA fingerprints, we can assess how similar or different age classes or localities are related to each other. We took samples from five locations up to 4 km apart along the Cooraboolka Road.



Site locations collected in 2007 mapped onto Google Earth satellite image of the Cooraboolka Road area near Boulia Qld. Australia

DNA fingerprints revealed a high level of genetic diversity among the more than 100 trees analysed.



Genetic analysis showing relationships among all samples analysed and displayed using principle co-ordinates analysis plot. Samples closer to each other are more closely related to each other.

There was some evidence of site specific genetic diversity (purple bars on graph below) but this is within the range expected for the scale of sampling undertaken. The results suggest more common recruitment and interbreeding is occurring in these stands that may have been expected. This calls further into question the longevity and recruitment events of this *Acacia*. Research into the genetic structure of *Acacia peuce* is continues.

Water relations

Comparative water use studies have been conducted on Acacai peuce and the beefwood, (*Grevillea striata*). *A. peuce* and *G. striata* appear to operate at different $\Psi_{leaf/phyllode}$. The trees may be trapping different sources of ground water that are under different tension. Considering that the close juxtaposition of individuals of the species it is unlikely that they are tapping into surface soils with differing Ψ_{matrix}. Rather, it is more logical to propose that *G. striata* taps into ground water with less negative Ψ_{matrix} than that tapped by *A. peuce*. If so, the root system of *G. striata* should extend to greater depths than that of *A. peuce*. This proposition is testable. During 2012 we will be using ground penetrating radar to map root systems of *Acacia peuce* and other trees and will be better placed to interpret water flux data.

If neither species is trapping into ground waters that differ in hydraulic status then the differences in $\Psi_{leaf/phyllode}$ may reflect differences in the way water is extracted by each. Different water extraction strategies should be reflected in hydraulic architecture of the roots, stems and the leaves, features about which our knowledge is rudimentary. Do xylem length and breadth, xylem area, Huber values etc differ between the species? To date we have measured $\Psi_{leaf/phyllode}$ in *G. striata* and *A. peuce* but not of any of the other trees (e.g. *A. georginae, A. cambagei, A. victoriae, Corymbia aparrerinja, Owenia* sp, *E. camaldensis*) and thus do not know whether the $\Psi_{leaf/phyllode}$ values we have measured for *G. striata* and *A. peuce* are typical.

A. peuce appears to maintain a lower $\Psi_{phyllode}$ than *G. striata*, although we have no observations from plants growing under well-watered conditions. If this is a feature of *A. peuce*, rather than an indicator of stress at the site at which it grows, one might expect that *A. peuce* should lose less water per unit of stomatal aperture than *G. striata* (boundary layer and leaf temperature considerations aside). Perhaps also the low surface-volume ratio of the needle-like *A. peuce* phyllodes would be conducive to reducing H_2O-loss per unit of surface area. It was noted in 2007 that *A. peuce* phyllodes contain many thick-walled sclerophyllous cells that would presumably reduce phyllode water content and may reduce intra-phyllode membrane surface area.

Water flux data suggest that *Acacia peuce* is well adapted to the arid soil environment in which it exists. It uses water differently from *G. striata*, a much more widely distributed species, however we see no indication that its rarity and restricted distribution is indicative of it being a climatic relict with an inherently tenuous existence into the future.

Summary

The waddi tree stand at Boulia is the most numerous of the three known localities in which the tree grows. The stand comprises somewhere around 100,000 individuals and has extended geographically, and in density since the 1970s. The stand maintains a high genetic diversity and is actively recruiting. We believe it to be in good health.

Waddi trees recruit opportunistically and depend on canopy seed storage to supply seeds, most of which die unless there has been above average rainfall. Seedlings send down a rapidly growing tap root in order to keep up with subsidence of the soil wetting front. They establish best on sandy sites which allow rapid root penetration and extraction of water at low soil water potentials but do not persist on source bordering dunes. There are indications that waddi trees can reproduce by suckering from shallow horizontal roots. The extent of asexual reproduction in the stand has yet to be fully evaluated. The horizontal roots probably play a water storage function in addition to acting as reservoirs for buds. The anatomy and function of shallow roots is under active investigation.

Grazing activity is not presently affecting the health of the stand. Cattle, kangaroos and camels browse foliage, devour seedlings and trample roots however they also reduce the significant risks to the stand posed by uncontrolled fire. Waddi trees exhibit structural adaptations to browsing by vertebrates and we believe this to contribute to their resilience to grazing in this the wettest part of their range.

Waddi trees do not appear to be extremely long lived. Radiocarbon dating suggests that the majority of large trees are approximately 200 years old. Some exceptional individuals may live longer but the beginning of senescence in trees of the sizes dated suggests that the majority would die inside 300 years.

Water use studies suggest that waddi trees are strongly drought adapted and their scarcity at a landscape scale does not reflect confinement to refugial habitat by water stress. There are indications that waddi trees use water differently from potential competitors such as *Grevillea striata* and this will be one of the areas of focus for continuing research on the species.

References

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