Callitris in the woodlands and shrublands of southern Western Australia: ancient landscapes, contemporary issues.

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Abstract: Western Australia is renowned for its iconic tall forests of jarrah, karri and tingle in the mesic south-west corner of the state. Less well known, but of equal interest and significance are the extensive woodlands and shrublands of the semi-arid zone. These ecosystems occur on land surfaces of great antiquity, with *Callitris* prominent as a small to medium sized tree. Six species of *Callitris* occur in Western Australia, with *C. drummondii* and *C. roei* endemic to the South West Botanical Province. *C. columellaris* and *C. preissii* are the most widespread and exhibit remarkable flexibility in the sites on which they occur and in their growth habit, varying from small stunted trees on granite and ironstone substrates through to stately trees on more favourable sites. The longevity and distinctive growth rings of *Callitris* make them well suited to dendrochronology and exploratory research has demonstrated the feasibility of establishing cross-dated chronologies extending back 350 years or more. Tree ring chronologies from *Callitris* have potential to provide a much needed historical context for projected climate change scenarios across southern Western Australia. The sandplain shrublands where *C. preissi* and *C. roei* principally occur tend to burn every few decades with fires of sufficient intensity to kill mature trees. Ring counts of *Callitris* stems provide a means to determine the time interval since the last fire and can assist in validating fire history information obtained from air photography and satellite imagery. Fire regimes in landscapes where eucalypt woodlands are interspersed with sandplain shrublands deserve further study as the recent history of large, intense fires appears incompatible with the development and continued persistence of mature eucalypt woodlands. The forestry profession has a long association with the woodlands of southern Western Australia through its management of harvesting operations for sandalwood and mining timber. Future opportunities for the forestry profession include raising awareness of the value of woodlands, managing fire regimes to optimize carbon sequestration in long-lived woody vegetation, and unlocking information about past climate variability.

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Introduction

Western Australia is renowned for its iconic tall forests of jarrah (*Eucalyptus marginata*), karri (*E. diversicolor*), marri (*Corymbia calophylla*) and tingle (E. *jacksonii*, *E. guilfoylei* and *E. brevistylis*) in the mesic south-west corner of the state. Less well known, but of equal interest and significance are the extensive semi-arid woodlands and shrublands of the southern interior of the state (Kessell and Stoate 1936, Kealley 1991, Yates *et al.* 2000). These ecosystems occur on land surfaces of great antiquity derived from Archean granite and gneiss of the Yilgarn craton, intersected by greenstone ranges and banded ironstone formations (Beard 1998). The surface of the Yilgarn plateau is gently undulating at elevations between 200 and 600 m above sea level. Drainage is occluded with extensive salt lakes associated with ancient paleo-drainage systems.

Semi-arid woodlands and shrublands once extended throughout the Coolgardie and Mallee bioregions (Thackway and Cresswell 1995) but much of the western half of the Mallee bioregion has been cleared for agriculture. The State vermin barrier fence extends north-west from Ravensthorpe and forms a distinct boundary between agricultural lands in the west and the sparsely populated tracts of unallocated crown land and conservation reserve that lie to the east. Areas to the north and east of the town of Coolgardie are held under pastoral lease. The large extent and relatively intact condition of woodlands and shrublands in southern Western Australia make them significant on a national scale, akin to the brigalow and cypress woodlands of western NSW and southern Queensland.

Callitris species occur as shrubs and small to medium sized trees throughout much of the woodland and shrubland in southern Western Australia. However *Callitris* has received little attention from foresters and ecologists in the state, probably because most species are of small stature, rarely form pure stands over large areas and have not been exploited commercially on a significant scale. Kessell and Stoate (1936) make no mention of *Callitris* in their paper on the arid forests of southern Western Australia, while Bowman and Harris (1995) drew attention to the paucity of information for a number of *Callitris* species. Arid zone forestry in Western Australia has focused on the Goldfields eucalypts which have been harvested on an extensive scale for firewood and mining timber and on Sandalwood (*Santalum spicatum*) which has been exploited for its aromatic oil (Kealley 1991, Bunbury 1997).

My aim in preparing this paper is to draw attention to some notable aspects of the distribution and ecology of *Callitris* in southern Western Australia, and in doing so to highlight important land management issues affecting the woodlands and shrublands in which *Callitris* occurs.

Distribution and occurrence of *Callitris* in Western Australia

Six of the *Callitris* species recognized in the recent taxonomic revision by Farjon (2005) occur in Western Australia namely *C. canescens*, *C. columellaris*, *C. preissii*, *C. verrucosa*, *C. roei* and *C. drummondi*, the latter two species being endemic to the South West Botanical province. *C. columellaris* is broadly distributed across the continent and within Western Australia occurs extensively on the Yilgarn plateau and in the Pilbara, Kimberley and arid interior. Specimen records indicate that C.

columellaris occurs in 14 of the 26 IBRA bioregions in Western Australia (Table 1). This distribution spans a remarkable range of climatic conditions from the dry mediterranean environment of the south west to the wet-dry tropics of the north Kimberley and the low, irregular rainfall of the arid zone.

C. preissi is also widely distributed throughout southern Western Australia, with specimen records from 8 bioregions including the Swan Coastal Plain. The distribution of *C. preissi* overlaps with that of *C. verrucosa* towards the drier inland margins in the Murchison and Great Victoria Desert bioregions, although *C. verrucosa* is probably poorly collected due to the remoteness of the areas in which it occurs. *C. canescens* is widespread throughout the Avon Wheatbelt and western parts of the Mallee bioregion, and also occurs on the Geraldton Sandplain in association with *Actinostrobus,* a native conifer genus endemic to the South West Botanical province.

Table 1. Occurrence of *Callitris* species by IBRA bioregions based on specimen records from the Western Australian Herbarium (http://florabase.dec.wa.gov.au).

IBRA Bioregion	*C canescens*	*C. columellaris*	*C. drummondii*	*C. preissii*	*C. roei*	*C. verrucosa*
Avon Wheatbelt	Y	Y		Y	Y	
Carnavon						
Central Ranges		Y				
Central Kimberley		Y				
Coolgardie	Y	Y		Y		Y
Dampierland						
Esperance Plains	Y		Y	Y	Y	
Gascoyne		Y				
Geraldton Sandplain	Y	Y				
Gibson Desert		Y				
Great Sandy Desert						
Great Victoria Desert		Y		Y		Y
Hampton				Y		
Jarrah forest						
Little Sandy Desert						
Mallee	Y	Y	Y	Y	Y	
Murchison	Y	Y		Y		Y
North Kimberley		Y				
Nullarbor						
Ord Victoria Plain						
Pilbara		Y				
Swan Coastal Plain	Y					
Tanami						
Victoria Bonaparte		Y				
Warren						
Yalgoo		Y		Y		

The two *Callitris* species endemic to Western Australia (*C. drummondii, C. roei*) have a southerly distribution concentrated in the Esperance Sandplains and Mallee bioregions, with scattered outliers of *C. roei* in the Avon Wheatbelt (Table 1). *Callitris* does not occur in the main belt of tall forest covered by the Jarrah Forest and Warren bioregions, although the distributions of *C. drummondii* and *C. roei* overlap with that of jarrah and marri at the southern end of the Stirling Ranges.

C. columellaris and *C. preissii* exhibit remarkable flexibility in the sites on which they occur and in their growth habit, varying from small stunted trees on granite and ironstone substrates through to tall trees on more favourable sites (Figure 1). Both species also occupy sites at a range of positions in the landscape. *C. columellaris* is commonly found around the margins of salt lakes on the Yilgarn plateau but also occurs at elevations approaching 1200 m above sea level near the highest summits in the Hamersley Range in the Pilbara. The elevation range for *C. preissii* is also substantial and extends from sea level to above 600 m on the summit of Peak Charles.

The population of *C. preissii* on Bald Island 50 km east of Albany offers an interesting insight into the growth potential of this species under mild coastal conditions with annual rainfall >800 mm and low potential evaporation. In this environment *C. preissii* grows to a stately single-stemmed tree >15 m tall with fine branching resulting from densely stocked sapling stands (McCaw 1997). Interestingly, trees of such stature are not found on comparable sites on the nearby mainland and there is scant evidence that they may have existed in the period since Europeans settled at Albany in 1826. Abbott (1981) noted that sea level rise during the Holocene has resulted in substantially different fire regimes for island and mainland ecosystems along the south coast of Western Australia.

C. canescens, *C. drummondii* and *C roei* appear to have more specific site requirements, with the result that the variability in growth habit is less than for *C. columellaris* and *C. preissii.*

Figure 1. Examples of the wide variation in growth habit of *C. preissii* in south-western Australia. Tall trees on Bald Island, near Albany (left), fire-killed mature tree in sandplain scrub heath east of Lake King (centre), dwarf plant growing in fissure of granite inselberg at Peak Charles (right).

Dendrochronology of *Callitris* – a window into the past or a glimpse of the future?

Callitris has several attributes that make it attractive for dendrochonological studies including longevity, durability and formation of annual growth rings (Ogden 1978, Banks and Pulsford 2001). Pearman's (1971) study of *C. preissii* growth rings on Garden Island near Perth, represents an important milestone in Australian dendrochonology, despite the fact that intra-annual and missing rings resulted in poor accuracy of dating. The next significant development in Western Australia came 15 years later with the development of a 650 year chronology for *C. columellaris* at Lake Barlee in the Murchison district (Perlinski 1986). Stem sections came from trees at least several hundred years old growing around the margins of the salt lake.

Growing awareness of climate change has stimulated interest in denrochronology, and tree ring chronologies have the potential to provide a much needed historical context for projected climate change scenarios. Cullen and Grierson (in press) investigated natural variability in rainfall in south-west Western Australia using a 350-year chronology from *C. columellaris* located on the southern edge of Lake Tay in the Coolgardie bioregion. The chronology showed significant correlation with regional rainfall anomalies over the autumn-winter (March to September) period and explained 54 % of variation in rainfall over a 90 year calibration period. Autumn-winter rainfall was reconstructed back to 1655 AD, revealing considerable multi-decadal variability in rainfall. Rainfall exhibited fluctuations from dry periods often lasting 20 to 30 years to periods of above average rainfall that persisted for 15 years or so.

A recent study by Sgherza (2006) has shown that *C. preisii* and *C. cansecens* also have considerable potential for use in climate reconstructions. These species are of particular interest as they occur within the Avon Wheatbelt, Esperance and Mallee bioregions where current trends of declining autumn-winter rainfall and increased temperatures are ominously similar to climate change predictions (Indian Ocean Climate Initiative 2001, Whetton *et al.* 2005). Finding old trees suitable for dendronchonology will be difficult for *C. canescens* because so much of the Avon Wheatbelt has been cleared for agriculture.

Fire in *Callitris* landscapes

Summer brings hot dry winds and regular lighting storms to southern Western Australia and in remote areas fires can burn for months growing to very large size (> 400 00 ha). Fire spread patterns are strongly influenced by landscape features such as salt lakes and by the pattern of fuel ages resulting from previous burning (McCaw and Hanstrum 2003). The sandplain shrublands where *C. preissi* and *C. roei* principally occur tend to burn every few decades with fires of sufficient intensity to kill mature trees. Fires limit tree longevity and consume dead wood, thereby eliminating evidence of past distribution and stand structure. Ring counts of *Callitris* stems provide a means to determine the time interval since the last fire and can assist in validating fire history information obtained from air photography and satellite imagery. Such information is important in remote areas where no other fire history records exist. Fire regimes in landscapes where eucalypt woodlands are interspersed with sandplain shrublands deserve further study (McCaw *et al.* 2006) as the recent history of large, intense fires appears incompatible with the development and continued persistence of mature eucalypt woodlands (Figure 2). Despite the difficulties in finding old trees in fire prone landscapes a systematic search of rocky breakaway slopes, granite outcrops and salt lakes might yield valuable dendrochronological information to improve our understanding of climate variability over the past 2-3 centuries.

Figure 2. Severe fire damage to eucalpyt woodland north-west of Peak Charles. following a lightning-caused fire in January 1991. Photographed May 1993.

Much remains to be learnt about the regeneration ecology and population dynamics of *Callitris* species across their environmental and geographic ranges. My observations of *C. preissii* regeneration following wildfires suggest that on occasions seedling emergence may be delayed for a number of years after seed is released from cones on fire-killed trees. Four years after an extensive wildfire north-west of Peak Charles in January 1991 I was unable to find more than a handful of seedlings around fire-killed mature trees. A return visit to the same trees in May 2000, nine years after fire, revealed abundant seedling regeneration. Seedling densities around parent trees were roughly proportional to the size of the tree and the number of cones present (Table 2).

Table 2. Attributes of ten *C. preissii* trees killed by fire in January 1991 and seedling regeneration recorded within 5 m radius of each tree in May 2000.

Tree No.	Height (m)	Diameter (cm)	No. of cones	Seedling density (m^{-2})	Seedling height min-mean-max (cm)
1	2.1	5	50-100	0.42	10-15-31
2	1.4	3	<50	0	-
3	2.6	7	<50	0	-
4	2.6	6	<50	0	-
5	4.6	17	>200	0.82	10-26-60
6	6.0	20	50-100	0.24	12-21-53
7	3.0	13	<50	0.16	8-19-32
8	2.5	9	<50	0	-
9	3.5	8	<50	0.05	15-19-26
10	2.5	8	100-200	0.18	20-29-52

What role for the forestry profession in managing *Callitris* landscapes ?

The forestry profession has a long association with the woodlands of southern Western Australia through its management of harvesting operations for sandalwood and mining timber (Kealley 1991, Bunbury 1997). While *Callitris* has traditionally provided the mainstay of the timber industry in western New South Wales and southern Queensland, harvesting of *Callitris* in Western Australia has been limited by the small and scattered resource with most timber destined for local use on pastoral stations. Slow growth rates are a disincentive to silvicultural intervention in natural stands or afforestation with *Callitris*.

Prospecting and mining continues to be the dominant economic activity throughout the more remote areas of southern Western Australia with major operations extracting gold, nickel and iron ore. Recent strong demand for iron ore driven by the booming Chinese economy has resulted in a number of new mine developments based on extraction of ore from banded ironstone formations. Banded ironstones occur on many of the major ranges in the southern interior of the state, which also have high conservation value because of their unusual soils and topography. These ranges are likely to have acted as refugia during past climate fluctuations and support a distinct flora with a high level of local speciation (Gibson and Lyons 1998 a, b). While most mining operations are confined to a relatively small part of an otherwise vast landscape, there are significant flow-on effects from road construction and improved access to previously remote areas. While not necessarily negative, these effects need to be recognized and any adverse impacts managed accordingly.

Land management issues in the semi-arid zone are now attracting greater attention from the conservation movement. The Gondwana Link project (www.gondwanalink.org) is a landscape scale vision to reconnect country across south-western Australia in which entire ecosystems, and the fundamental ecological processes that underpin them, are restored and maintained. The project involves individuals and local, regional and national conservation groups working to restore ecological connectivity from the woodlands of the drier interior to the tall wet forests in the far south-west corner. Engagement with projects such as Gondwana Link could provide important opportunities for the forestry profession to raise awareness of the value of woodlands, and to contribute the professions considerable knowledge of woodland ecology, silviculture, fire management and environmental history. Forestry expertise could also contribute to designing and implementing fire regimes to optimize carbon sequestration in long-lived woody vegetation.

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