



Australasian Plant Conservation

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Buttongrass moorland in Tasmania – what and where?
Is global environmental change end game for prehistoric vegetation legacies?
Impacts and management of recreational walking on Buttongrass moorland
Lichens: an overlooked Lilliput in Tasmania's Buttongrass moorlands
Fire and *Sphagnum* in Tasmania
And much much more.....

SPECIAL THEME: BUTTONGRASS MOORLAND – CONSERVATION AND MANAGEMENT

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Australasian Plant Conservation

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Front cover: Mosaic of vegetation communities, including Buttongrass moorland, Mount Anne, Tasmania. Photo: Grant Dixon
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Introducing 'Conservation and management of Buttongrass moorland'

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Buttongrass moorlands were the focus of a workshop held in Hobart in July 2007, and several presentations are included in this issue. The taxon that most characterises Buttongrass moorland is the tussock sedge *Gymnoschoenus sphaerocephalus* (Buttongrass). The genus *Gymnoschoenus* is endemic to Australia and has only two species, *Gymnoschoenus sphaerocephalus* and *G. anceps*. The first species has its greatest abundance in Tasmania, but is distributed widely in nutrient-poor, cool temperate, wet and poorly drained sites along the coastal and upland regions of eastern Australia as far north as southern Queensland. It also has a very restricted distribution in the southeast of South Australia, where it is listed as endangered. The other species, *G. anceps*, is restricted to the southwest coastal region of West Australia, where it also occurs in swamps and seasonally wet flats.

The extensive dominance by *Gymnoschoenus* of Tasmania's sedgeland and wet heaths has led to this ecosystem being dubbed 'Buttongrass moorlands' in Tasmania. Elsewhere in Australia analogous vegetation may be referred to as bog, swamp, sedgeland or wet heath. An example of analogous vegetation in New South Wales that includes Buttongrass moorland in its range of variation is the nationally listed community 'Temperate highland peat swamps on sandstone' (*Environment Protection and Biodiversity Conservation Act 1999*).

This issue of *Australasian Plant Conservation* focuses on studies of Tasmanian Buttongrass moorlands. The opening article by **Sib Corbett** and **Jayne Balmer** describes the variation in structure and floristics of Buttongrass moorlands in Tasmania and how these have been partitioned into mapping classes for the state-wide 1:25,000 vegetation map 'TASVEG'. The article provides detailed ecological descriptions of the major mapping classes used for the western Tasmanian Blanket Moors.

In relation to reservation of Buttongrass Moorland, an analysis of TASVEG 1.0 mapping (TVMMP 2005) shows that within Tasmania more than 89% of this ecosystem is reserved. Mapping of Buttongrass into detailed mapping categories has been almost completed for the West, Central Highlands and the Southern Ranges Bioregions where Buttongrass moorlands are extensive and all classes are well reserved. Mapping of Buttongrass moorlands in other nationally recognised bioregions (IBRA) has not yet distinguished the vegetation into detailed mapping units. The percentage of Buttongrass moorlands reserved exceeds 40% for all

bioregions in which it occurs. However the Flinders and South East bioregion have less than 200 ha each while the King Bioregion may have rare floristic types associated with the rare occurrence of Buttongrass moorland on rich alluvial soils on basalt (Jarman *et al.* 1988). More detailed mapping is therefore still required to ensure that Comprehensive and Adequate Reservation has been achieved in all Tasmanian bioregions (Gilfedder *et al.* 2007).

David Bowman provides an intriguing comparison of the ecosystem dynamics in southwest Tasmania (where highly flammable Buttongrass moorland is extensively juxtaposed with fire sensitive forest) with the vegetation mosaics of Spinifex hummock grasslands and Mulga shrubland in central Australia. He demonstrates that the boundaries within these mosaics in Central Australia are essentially held in place by differences in soil nutrients that have resulted from differences in fire history. Climate change has the potential to alter fire frequencies significantly, which may destabilise the vegetation boundaries, altering vegetation and soils.

Karen King used simulation modelling to determine the likely outcomes of altering patterns of prescribed management burning in Buttongrass moorlands in terms of reducing the impacts of wildfires on life, property and biodiversity values. Her modelling suggests that 10% of the extent of Buttongrass moorlands will need to be burnt annually to significantly reduce the frequency and size of wildfire events and to lower the probability of burning fire sensitive vegetation and other assets. Current annual management burns within Buttongrass moorland in southwest Tasmania fall far short of the optimum extent of burning proposed by the modelling.

Aspects of the flora of Buttongrass moorlands are described in several articles in this issue. **Naomi Lawrence** and her coauthors describe the floristic values contained within this ecosystem providing examples of restricted endemics, primitive taxa and rare and threatened flora. They also briefly document the characteristics of the flora that make it one of the most flammable vegetation types in the world. Scleromorphic graminoids with high silica contents and leaf surface to volume ratios have resulted in long term retention of dead leaves within the plant which are resistant to decay. The consequence is an aerial fuel array that dries quickly allowing this vegetation to burn following one day without rain (Marsden-Smedley and Catchpole 1995).

James Wood and **Micah Visoiu** describe the preliminary results of seed collection within Buttongrass moorlands undertaken as part of the global 'SeedSafe' project. They found that a number of species have very poor seed viability and suggest that fire may be needed to stimulate seed production in some species. **Jennie Whinam** describes the short term impacts of fires within Buttongrass moorlands on remnant *Sphagnum* peatland communities, demonstrating that single fire events can reduce *Sphagnum* from nearly ubiquitous to only a minor presence. Relationships between fire and other bryophyte species are described by **Mikayla Jones** in her account of the bryophyte communities of Buttongrass moorlands. **Gintaras Kantvilas** continues the theme of non-vascular species, describing the lichens of Buttongrass moorlands in Tasmania and the various specific habitats they occupy. Kantvilas points out that it is important when managing Buttongrass moorlands to appreciate the lichen diversity and understand these habitats.

An overview of the fauna and its ecology, including both vertebrates and invertebrates, is provided by **Michael Driessen**. His article is followed by a detailed account of one of the keystone fauna within Buttongrass moorlands, the Burrowing Crayfish, by **Alastair Richardson** and **Neil Doran**. The burrows of these invertebrates provide a ventilation system within the otherwise anaerobic soils when they are fully saturated, considerably enhancing plant growth. Another group of soil dwellers are the soil mites. **David Green** reveals the richness and diversity of these fauna within Buttongrass moorland and discusses the relationship between the mite communities and vegetation age.

Peter Tyler describes the limnology of Tasmania's waters, including the characteristics that set those of southwest of Tasmania apart from the rest. In the southwest, extensive distribution of organic soils results in tannin-stained waters, which provide a distinctive environment for rare and endemic algae and other micro-organisms.

The major threat to Buttongrass moorlands of Tasmania, apart from climate change, is that posed by the plant pathogen *Phytophthora cinnamomi* (Root Rot). The serious nature of this threat is described by **Rudman** and **Balmer**. One of the ways in which this disease is spread is by the movement of infected soil on bushwalker's boots. There is also a high risk of spread with track work and maintenance operations, which involve helicopter transport of digging equipment and track materials. **Grant Dixon** describes other impacts of recreational walkers in the final article of the bulletin.

Bush walkers have some of the greatest impacts directly and indirectly on Buttongrass moorlands, but it is not clear that they gain much pleasure from travelling across boggy Buttongrass plains. In fact, this vegetation is probably the least appreciated and valued in Tasmania. Grant (2007) demonstrated that the most common words people use in recounting experiences of Buttongrass are "hated, useless, wretched, monotonous, drab-coloured,



General view of Buttongrass moorland. Photo: Nicki Chilcott

insecure, exasperating, hazardous, sour, waste." Yet the Buttongrass moorlands of the Tasmanian Wilderness World Heritage Area are beautiful, diverse and contain values that meet all four natural criteria for World Heritage Listing (Balmer *et al.* 2004).

The Buttongrass moorland management workshop was held as one of a number of events to celebrate the 25th anniversary of the inscription of the Tasmanian Wilderness upon the UNESCO World Heritage list. As part of the workshop and these celebrations, a small nature writing prize was offered for the best prose and poetry entries inspired by Buttongrass. The winning poetry entry 'Buttongrass' by **Adrienne Eberhard** (p 17) is a beautiful piece of poetry that one of the judges Gina Mercer noted 'resonates with understated meaning long after you have finished reading it.' The prose entry 'A carnivore in fairy's clothing' by **Janet Fenton** (p 5) enchants and delights the reader whilst providing a clear and vivid account of some fascinating plant species within Buttongrass moorland. The importance of story in developing a love for and appreciation of the natural world cannot be underestimated and it is hoped that these works will inspire further positive accounts of this most fascinating ecosystem.

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Buttongrass moorland in Tasmania – what and where?

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Introduction

Buttongrass moorland covers about 8% of Tasmania, occupying about 572,000 ha (TVMMP 2005). This is less than earlier estimates of one million hectares, which were based on 1:500,000 mapping and included large areas of scrub vegetation within the Buttongrass mapping unit (Kirkpatrick and Dickenson 1984).

In 1988 Jarman *et al.* described Buttongrass moorland as treeless or sparsely treed vegetation in which *Gymnoschoenus* is a typical component. They also included within their definition of Buttongrass moorland small islands or strips of related vegetation that lack *Gymnoschoenus* but occur within or juxtaposed to vegetation containing Buttongrass. Examples of these communities would include small copses of scrub or riparian vegetation within a sea of treeless Buttongrass-dominated vegetation. Buttongrass moorland in this definition is a landscape or ecosystem of geographically and floristically related vegetation communities.

Jarman *et al.* (1988) split Buttongrass moorlands into two groups - Blanket Moor and Eastern Moor, based on floristic and terrain factors. Blanket Moor accounts for much of the Buttongrass moorland in Tasmania, and is confined to the western half of the State where rainfall is high. In southwest Tasmania Blanket Moor is mostly underlain by Precambrian metasediments and their derivatives. Further north substrates are more variable, although essentially siliceous. Blanket Moor extends beyond the poorly drained flats to occupy well drained slopes, ridges and plateaux from sea level up to 1050 m, where the lack of nutrients and frequent fires limit tree growth.

Eastern Moor is restricted to poorly drained topographic situations of northern, central and eastern Tasmania on a variety of substrates. On the southeastern Central Plateau it is widespread on peaty flats developed on dolerite. In northeast Tasmania it can be found on broad plains underlain by siliceous sediments (e.g. Mathinna Plains) and undulating granite plateaux on Blue Tier, both at 700–800 m, and on granite at Mt. Graham at 500 m. Eastern Moor communities at low elevations are most extensive between Southport and South Cape Bay in southern Tasmania occurring on a variety of substrates. They also occur in small patches (often too small to map) in other eastern and northern Tasmanian bioregions.

Shrub dominated Buttongrass associations are common in southwest Tasmania but also occur in a few places

in northern and northeast Tasmania. Vegetation almost purely of *Gymnoschoenus* occurs on alluvial flats and is a community shared between Blanket and Eastern Moor.

The highland transition

The Moorlands that occur on quartzite and siliceous glacial gravels on subalpine plains around Cradle Mountain are mapped as Eastern Moor because of their floristic affinities. These moors generally have a prominent *Gleichenia alpina* component or form mosaics with pure *Gleichenia* fernland. Moorlands at higher elevation on the quartzite ranges to the northwest of Cradle Mountain are floristically transitional between high altitude Eastern Moor and Blanket Moor. It should be noted that Buttongrass moorland does not extend into the true alpine zone.

Mapping the Buttongrass moors

Jarman *et al.* (1988) provided approximate geographic distributions of Buttongrass communities within a 10 square kilometre grid across Tasmania, but polygon boundary mapping below the level of a general 'Buttongrass moorland' class was not attempted until detailed vegetation mapping was commenced for the Tasmanian World Heritage Area (WHA) in 1989. The current whole-of-Tasmania vegetation map incorporates the WHA mapping (TVMMP 2005) and has several Buttongrass moorland units (Table 1, Harris and Kitchener 2005). However many Buttongrass moorland areas outside of the Tasmanian WHA have as yet only been superficially mapped into the undifferentiated mapping class *Buttongrass moorland (undifferentiated)*. A number of Jarman *et al.*'s (1988) Buttongrass moorland communities are too small to map and/or are not easily discernible from aerial photographs. These include 'Daisy Pans', 'Clay Pans', 'Mossy Sands', 'Sword Sedgeland' and 'Copse' communities. However 'Alkaline Pans' communities, located on outcropping limestone within Buttongrass valleys, are distinctive on aerial photos and have been mapped in areas where they occur most densely in the landscape. This community is listed as rare on Tasmania's threatened native vegetation list and has a total extent of less than 600 ha.

Eastern Buttongrass moorlands communities are only differentiated into three mapping units and are much less extensive than Blanket Moor. Most are attributed to the TASVEG mapping unit *Eastern Buttongrass moorland*. Some will also be mapped as *Pure Buttongrass moorland* when areas of undifferentiated Buttongrass

are distinguished into more detailed mapping classes. In addition to these, there are two communities transitional between Buttongrass moorland and other vegetation (*Highly grassy sedgeland* and *Restionaceae rushland*) which have their greatest extents in areas geographically associated with Eastern Moor.

Table 1. *Tasmanian Buttongrass Moorland mapping communities*

Blanket Moor	Eastern Moor
Indicator Species of Blanket Moor	Indicator Species of Eastern Moor
<i>Gymnoschoenus sphaerocephalus</i> (0-25% -50%) Buttongrass	<i>Gymnoschoenus sphaerocephalus</i> (50-75%)
<i>Epacris corymbiflora</i> , <i>E. heteronema</i>	<i>Epacris lamuginosa</i>
<i>Leptospermum nitidum</i>	<i>Leptospermum scoparium</i>
<i>Leptospermum glaucescens</i> in adjoining scrub	<i>Leptospermum lanigerum</i> in adjoining scrub
<i>Melaleuca squamea</i>	<i>Melaleuca squarrosa</i>
<i>Baeckea leptocaulis</i>	<i>Baeckea gunniana</i> high altitude
<i>Boronia elisabethiae</i>	<i>Boronia rhomboidea</i> , <i>B. pilosa</i>
<i>Gleichenia dicarpa</i>	<i>Gleichenia alpina</i> (high altitude)
<i>Agastachys odorata</i>	<i>Westringia rubiaefolia</i>
<i>Eucalyptus nitida</i> (in copses and on margins)	<i>Eucalyptus rodwayi</i> (sparse on margins)
<i>Eucalyptus vernicosa</i> scrub margins at high altitude	<i>Eucalyptus coccifera</i> , <i>E. pauciflora</i> (high altitude on margins)
TASVEG Mapping classes falling into Blanket Moor	TASVEG Mapping classes falling into Eastern Moor
Buttongrass moorland (undifferentiated)	Buttongrass moorland (undifferentiated)
Pure Buttongrass moorland	Pure Buttongrass moorland
Buttongrass moorland with emergent shrubs	Buttongrass moorland with emergent shrubs
Sparse Buttongrass on slopes	
Western Buttongrass moorland	
Western lowland sedgeland	
	Eastern Buttongrass moorland
	Highland grassy sedgeland*
Alkaline pans*	
Restionaceae rushland*	Restionaceae rushland*

* *Gymnoschoenus sphaerocephalus* is absent or rare in these vegetation types but they are part of the mosaic of communities occurring within landscapes dominated by Buttongrass moorland or they comprise a floristic assemblage similar to Buttongrass moorland vegetation.

Blanket Moorland classes in western Tasmania

Detailed ecological descriptions are provided here only for the Blanket Moor mapping classes of western Tasmania in which *Gymnoschoenus sphaerocephalus* is a typical component. The distinction between classes is determined by floristic composition, vegetation structure and percentage cover of the most common species present. Differences between classes relate to soil characteristics, which in turn appear to be related to fire history and slope. Variations within the communities are predominantly affected by environmental factors such as soil depth and moisture but fire frequency and time since fire do affect floristic composition and vegetation structure to a lesser extent. There are indications that interpretation of multi-spectral remote sensing data will in the future validate existing moorland classes and will help to clarify their distribution in remote areas.

Pure Buttongrass moorland is uncommon in southwest Tasmania and is generally restricted to small and sheltered alluvial plains and riparian margins. *Gymnoschoenus sphaerocephalus* dominates, often as large tussocks, with a few spindly emergent shrubs, particularly *Sprengelia incarnata* and sometimes *Leptospermum nitidum*. *Pure Buttongrass moorland* is more common in Eastern Moor, where it is floristically more diverse.

Western lowland sedgeland is variable in floristic composition, from sparse graminoids scattered over muddy ground, to a dense sedgy heath up to nearly 1 m tall. Both these forms have very low cover of *Gymnoschoenus sphaerocephalus* (5-10%), and instead are dominated by cord rushes such as *Chordifex hookeri*, *Sporadanthus tasmanicus* and *Eurychorda complanata*. *Winifredia sola* is a faithful species. Emergent shrubs taller than 1 m (e.g. *Leptospermum nitidum*) are uncommon. The sparse forms of *Western lowland sedgeland* grow on poorly drained broad plains in southwest Tasmania, such as the Rowitta, Melaleuca and Louisa Plains. Dense, sedgy heath forms occur on the Tertiary gravel terraces south of Macquarie Harbour and on coastal plains and inland valleys such as the Arthur Plains. This community has few *Phytophthora cinnamomi* sensitive species (see Rudman and Balmer this issue p 29-31) and is quick to recover from fire.

Sparse Buttongrass moorland on slopes is the most abundant moorland class in southwest Tasmania, occupying rocky or gravelly quartzite mountain sides and alluvial gravel fans at the feet of the ranges. Plants provide sparse cover and are decrepit; the open ground is usually coated with algal slime (*Nostoc* sp.) around struggling *Stylidium graminifolium*, *Boronia parviflora* and lycopods. *Chordifex hookeri* is often co-dominant with *Gymnoschoenus sphaerocephalus* and there are other graminoids and small shrubs such as *Sprengelia incarnata*, *Bauera rubioides* and *Epacris corymbiflora*. *Melaleuca squamea*, *Leptospermum nitidum* and *Baeckea leptocaulis* may be present and emergent *Banksia marginata* increases with increasing elevation. The geographic range of *Sparse Buttongrass moorland on slopes*, coupled with occurrences of dense pedestals of *Western Buttongrass moorland* within the community, suggests this community has been derived from *Western Buttongrass moorland* by burning.

Western Buttongrass moorland includes dense graminoid heathland up to 1 m tall, with up to 25% (rarely up to 50%) cover of *Gymnoschoenus sphaerocephalus*. *Empodisma minus* and cord rushes are co-dominant. *Sprengelia incarnata* is nearly always present and woody shrubs, particularly *Leptospermum nitidum* and *Melaleuca squamea* are common in most areas. *Banksia marginata*, *Agastachys odorata* and *Cenarrhene nitida* are common emergents. Herbs and Lycopods grow in the inter-tussock spaces. This community has many species highly sensitive to Root Rot, *Phytophthora cinnamomi*.

After fire most of the graminoids readily re-sprout and herbs germinate or resprout to take advantage of the

temporarily increased light and nutrients available in the intertussock spaces. The shrubs and in particular *Banksia marginata*, *Bauera rubioides* and *Melaleuca squamea*, which usually recover from seed, are slower to recover. After prolonged periods without fire the shrubs may overgrow the sedges and form a partially closed canopy and *Western Buttongrass moorland* converts to *Buttongrass moorland with emergent shrubs*.

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Carnivores in Fairies' Clothing

Janet Fenton

A year-old burn is red with tentacles. Low sun catches a rainbow in every orb fringing the fingers of sundews. A hectare of them. Slowly I walk down a slope through the sundews, feet crunching on brittle sticks and half burnt sedge. The ground is firm, packed with a dense root mat, but it has a spring to it, welcome to the legs after hard pavement. Black buttongrass tussocks sprout rampant green growth. Meandering runways made by native rodents are obvious now that the sheltering tussocks have burnt away. A Dusky Robin perches on a *Melaleuca* twig, watching for movement. Dew dangles on spider silk; trapping light in the sundew forest – a forest of carnivores, for it is not only the spider that snares its prey. A small dark shape struggles its last in a glob of stickiness. The black-fly's kicking grows weaker, less frequent, and gradually it is digested, welcome nutrient for the sundew in this poor peat soil. The spider looks on. Does she ever dare to steal?

Sundew shapes are a marvel. Forked ones, *Drosera binata*, comprise this sundew forest. Delicate spears emerge from the earth, unrolling transparent, wine-red fronds, inviting insects to taste their nectar. Sweet-scented flowers proclaim white innocence. Another species, the Pygmy *Drosera*, is minute. Its crimson rosettes stud the earth, shining like brooches on a black dress. And there are others: *D. arcturi*'s long red tongues protrude from the plain, like animals underground lapping at the air; hairy tongues, moist with digestive juices. And *Drosera spathulata*, with its rosette of spoons, hugs the ground, waiting.

Beyond the burned area, sedges swish against my calves. Where the plain is flat, boggy and waterlogged, dainty Fairy's Aprons, *Utricularia*, fringe dark pools. Their purple aprons fly from slender masts, a spatter of colour against black peat mud. But these are carnivores in fairy's clothing, for below is another story, another world. Down there lurk shapes even Tolkien never dreamed of. For who could imagine the shape of *Daphnia*? Who could

dream up an Ostracod or paint a Phreatoicid in their imagination? Who would cobble together a Copepod, or the segments of biting midge larva?

Below the surface they live out their secret lives in the peaty soup, flooded by rain, sometimes burying deeper for protection from the baking sun. But those traps the fairies set – what feats of engineering! Not only roots are hidden under the mud at the base of the fairies' masts. When we look at this end of the pretty herb, 'fairy's apron' becomes 'bladderwort'.

There is drama in the mud puddle! The fairy's trap is set, a pale orb in the peat slurry. A secret door waits, tight shut. A minute creature blunders and bumps into stiff bristles protruding from this bladder door – and springs the trap! The door swings inward; a rush of water sluices the victim over the threshold and into the hollow chamber. Slowly the door closes; the water stills. Glandular hairs begin the work of pumping the bilge, slowly excreting liquid until the water-pressure inside is lowered and once more the mechanism is set. Trapped, the creature is slowly digested: nutrient for a herb in an inhospitable environment. Another astonishing means of survival.

Purple flower heads and slender stems are reflected in the pool in quiet beauty. From above, I know nothing of the drama taking place below the surface – that world is on a different scale. Imagine Alice, disappearing into the wonderland of a mud puddle. What an alarming, adventurous realm! Pale creatures with many-jointed legs confront her, and other extraordinary, magnificent things sail by with bristles and bulges in unlikely places, organs visible through translucent body walls. Maybe a tadpole swims overhead, a giant dark blimp with a tail.

We, lumbering beings, blunder on oblivious of the minute world beneath our feet. The microcosm and for that matter, the greater cosmos, are beyond our experience. Yet, we can seek to understand.

Is global environmental change the end game for prehistoric vegetation legacies? The parallel cases of fire-maintained vegetation mosaics in southwest Tasmania and central Australia

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Introduction

In many Australian landscapes the vegetation is not what would be predicted from the current climate. This lack of direct connection between vegetation and climate is due to the combined effects of past climate change associated with the ending of the last ice-age, the introduction of Aboriginal landscape burning and megafaunal extinctions. Nevertheless, vegetation mosaics that are self-sustaining have arisen during the relative environmental stability of the last 10,000 years (the Holocene) due to fire-soil-vegetation feedbacks that developed under a regime of skilful Aboriginal landscape burning. Appropriate fire management is thus vital for the conservation of natural landscape mosaics such as in Southwest Tasmania. Global climate change is a further complicating factor in understanding fire-maintained vegetation mosaics. This article explores the past and future of the Mulga shrubland/Spinifex hummock grassland mosaic in central Australia and the Buttongrass moorland/Forest mosaic in Southwest Tasmania (Figs. 1 & 2).

Another green world – a world without fire

It is widely assumed that vegetation and climate are in equilibrium. For example, tropical rainforests are restricted to humid tropical climates. However, there is growing appreciation that landscape fires have radically disturbed

climatically determined vegetation. This point is well illustrated by the recent research by the South African ecologist William Bond and coworkers (Bond *et al.* 2005). They used a computer model of global vegetation patterns to show that the plant geography of the world changes markedly when simulated landscape fires are ‘switched off’. For example, in a ‘world without fire’ forests (defined as > 80% tree cover) doubled from 27% to 56 % of the land area.

Southwest Tasmania is a prime example where fire is thought to have ‘decoupled’ vegetation from climate. With its cool, mid-latitude oceanic climate, and an annual rainfall in excess of 2000 mm distributed throughout the year, western Tasmania is ideal for cool temperate rainforest yet treeless Buttongrass moorlands are widespread. The late Bill Jackson (Jackson 1968) explained this anomaly as being the legacy of sustained landscape burning by Tasmanian Aborigines.

The ecological influence of prehistoric peoples’ landscape burning remains scientifically contentious. For example, many ecologists in the U.S.A. consider Native Americans to be a negligible cause of past wildfires. In marked contrast there are controversial claims that increased ignitions following human colonization in the late-Pleistocene caused the extinction of Australia’s large marsupials, triggered the emergence of flammable ecosystems and changed the climate. A feature of these debates is the absence of robust



Left: Figure 1. The Mulga shrubland/Spinifex grassland mosaic in the Southern Tanami Desert.
Right: Figure 2. The Buttongrass moorland/Forest mosaic in Southwest Tasmania. Photos: David Bowman

historical data about the impact of Aboriginal fire use and the nature of vegetation change across landscapes.

The enigmatic Mulga/Spinifex mosaics of central Australia

The landscapes of central Australia are characterised by patches of closed-canopy Mulga shrubland, which are relatively fire-sensitive, embedded within a matrix of highly flammable Spinifex (*Triodia*) grassland. It is believed that vast areas of Mulga were converted to Spinifex by pre-historic Aboriginal landscape burning. There is concern that Mulga is now further retreating because of the current hostile fire regimes.

Stable carbon isotope analysis of soil organic matter is a useful way to tell if its vegetation predominantly consists of grasses (Spinifex) or trees (Mulga) and radiocarbon analysis can also provide dating of the soil samples. Thus by examining a core of soil it is possible to determine how the composition of vegetation has changed over time. Surprisingly, analysis of a Mulga/Spinifex mosaic in the southern Tanami Desert (Bowman *et al.* 2007) showed that the mosaic had remained stable over the last 2000 years. Further, sequences of historical aerial photographs showed that the spatial extent of Mulga patches changed little over the 52 year (1950 to 2002) study period when traditional Aboriginal fire management had largely ceased (Bowman *et al.* 2008). However, the modest changes that had occurred were restricted to within 50 m of boundaries between the shrublands and Spinifex grasslands. Statistical modelling showed that burning was responsible for these slight boundary movements and field studies of Mulga trees on the shrubland boundaries revealed a marked preponderance of regrowth and a loss of older trees due to fire damage.

Although there were no obvious environmental differences across the Mulga/ Spinifex boundaries, such as change in soil type or slope angle, Mulga shrublands were found to occur on more clay-rich soils with higher concentrations of total phosphorus, nitrogen and potassium compared to the surrounding Spinifex grasslands (Bowman *et al.* 2007). These differences reflect the effect of the less frequently burning of the Mulga vegetation that enables soils to build up their nutrient capital. In contrast, frequently burnt Spinifex grasslands have nutritionally impoverished soils.

In sum, a series of reinforcing fire-soil-vegetation feedbacks maintain the mosaic of Mulga patches. Yet the change from Aboriginal to the more contemporary landscape burning, that is currently degrading Mulga shrublands, has potential to cause the loss of the shrublands should this current fire regime continue. Thus the Mulga/Spinifex mosaic is held in a fine balance and any changes in fire regime that breakdown or amplify the fire-soil-vegetation feedbacks will ultimately change the distribution of Mulga and Spinifex. For example, climate change has the potential to change fire regimes via frequency of fire-promoting weather and production of fuel.



Figure 3. The destruction of peat soils in a Paperbark swamp on King Island by wildfire in the Summer of 2007. The relative contribution of various factors (such as severe summer drought or changed hydrology from artificial drainage) to the extreme soil dryness leading to the massive combustion of peat is not known. Nevertheless, the burning of organic soils is one of the potential effects of hotter and drier conditions in Southwest Tasmania. Photo: Phil Bell

Climate change and Buttongrass

While equivalent historical ecology studies haven't been done in Tasmania's landscapes, there are some striking parallels between the above case of the Mulga/Spinifex mosaic and the mosaic of forest and Buttongrass plains in Southwest Tasmania. First, it is widely accepted that prehistoric fire regimes have shaped the Buttongrass/Forest mosaic (Jackson 1968). Second, the mosaic is maintained by differences in soil type, particularly soil fertility. Finally, there is emerging evidence that Buttongrass plains existed throughout the Holocene and into the last ice-age (Fletcher and Thomas 2007). However, unlike the case of the Mulga/Spinifex mosaic, the Buttongrass plains in Southwest Tasmania are particularly vulnerable to climate change because the soil is rich in organic matter (peat). These peats will become increasingly flammable under the current trend of warmer and drier climates (Fig. 3). A critical gap in knowledge is the rate of peat accumulation. It is possible that the organic soils of Southwest Tasmania are at least 10,000 years old.

The world is currently warming rapidly. Over the last century global mean surface temperatures have risen by about 0.7°C and the rate of warming over the last 50 years is almost double that over the last century (0.13°C vs. 0.07°C per decade) (http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Pub_SPM-v2.pdf). While there is uncertainty about the ecological consequences of this warming, the prognosis for Australian environments is not good. For example, the Intergovernmental Panel on Climate change (IPCC) report entitled *Impacts, Adaptation And Vulnerability – Summary for Policy Makers* (<http://www.ipcc.ch/SPM13apr07.pdf>) states that there is 'very high confidence' that there will be significant loss of

biodiversity by 2020 in some ecologically-rich Australian sites including

- the Great Barrier Reef;
- Queensland Wet Tropics;
- Kakadu wetlands;
- Southwest Western Australia;
- Sub-Antarctic islands; and
- Alpine areas.

The IPCC report also notes a trend of declining forest productivity and more bushfires in Southeast Australia. The IPCC report omits Southwest Tasmania as a region at risk to climate change, which is an unfortunate oversight given this region is particularly vulnerable because the organic soils will become increasingly flammable under the current trend of warmer and drier climates. Climate change presents new challenges for the already vexed issue of fire management and the conservation of environmental values of the Southwest Tasmania World Heritage Area.

Management and research

Recognition that Southwest Tasmania has long been inhabited by humans, and has been transformed by skilful landscape burning, constitutes a paradigm shift from the outdated view the region was a 'wilderness' unaffected by people. Clearly, the conservation of cultural landscapes presents practical and philosophical challenges for fire managers because it is not possible to 'let Nature take its

course' – rather humans must actively manage fire. Climate change adds to the complexity of the fire management because of the increased risk that fires will destroy the organic soils, especially on steep slopes. In a warmer world burnt peatlands may not redevelop because of unfavorable climatological and hydrological conditions.

Given the threats to the iconic landscape of Southwest Tasmania, research is required to determine: (i) the rate, direction and magnitude of shifts in the boundaries of Buttongrass/Forest mosaics, (ii) the age and rate of accumulation of organic soils, and (iii) impacts of fire on Buttongrass moorland soils. It is time to revisit fire ecology of Southwest Tasmania using similar methodologies as used in Mulga/Spinifex mosaics. Applied research is also required to evaluate the efficacy and cost of various fire management options, in light of global climate change.

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The relative importance of 'fine scale fuel mosaics' in reducing fire risk in southwest Tasmania

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Introduction

Unplanned fires can be responsible for the loss of life and property, and may impact on biodiversity and the functioning of ecosystems. Land managers aim to reduce the fire risk posed by these unplanned fires on defined infrastructure, people and ecological values, primarily through the use of prescribed fire and suppression. In Australia there is an inherent assumption that the incidence and spread of unplanned fires is reduced where there is a high spatial variability in fire ages, and hence vegetation structure.

This 'fine scale fuel mosaic' is additionally believed to have positive effects on many ecological processes (e.g. Burrows and Wardell-Johnson 2003; Bradstock *et al.* 2005). Therefore, Australian fire managers emphasise prescribed burn patch size as an attribute that is assumed to be significant in influencing unplanned fire effects and enhancing landscape ecological responses. This study has used simulation modelling to explore the relationships between a number of prescribed burning attributes and fire risk, as well as the relative importance of 'fine scale fuel mosaics' in reducing fire risk in southwest Tasmania.

Methods

This investigation used the simulation model FIRESCAPE-SWTAS which combines a process-based landscape fire regime simulator and a vegetation dynamics model (Cary *et al.* 2006; King *et al.* 2006; King *et al.* in press). The model simulates natural fire regimes co-existing with a range of prescribed burning scenarios on a 1.8 million hectare landscape encompassing the Tasmanian Wilderness World Heritage Area and Southwest National Park (Fig. 1).

Prescribed burning parameters tested included (i) the annual proportion of the landscape receiving prescribed burning treatment (treatment level), (ii) the size of prescribed burning blocks, and (iii) the spatial array of these blocks. Fire effects analysed in response to combinations of these treatment parameters included (i) fire size distributions, (ii) the mean annual number of unplanned fires and (iii) the mean annual area burned by unplanned fires. To remain consistent with the present practice in southwest Tasmania of prescribed burning only in Buttongrass (*Gymnoschoenus sphaerocephalus*) moorland communities, treatments were confined to this vegetation.

Simulated treatment levels ranged from 0% to 50% of Buttongrass moorland communities annually prescribed burned, with prescribed burning block sizes ranging from 1 to 4000 hectares. Two alternate spatial patterns of prescribed burn blocks were simulated (Fig. 2). In both cases an appropriate number of blocks were selected to achieve a given level of annual treatment. For simulations with an ordered spatial pattern, treatment of adjacent prescribed burn blocks was lagged sequentially by one year, giving a relatively uniform distribution of inter-fire intervals. Alternatively the same number of blocks was selected randomly each year across the study area to give a more diverse distribution of inter-fire intervals. Some treatment combinations were included to specifically investigate the mathematical relationships between prescribed burn treatment parameters and various fire effects. Statistical analyses were performed on all outputs.

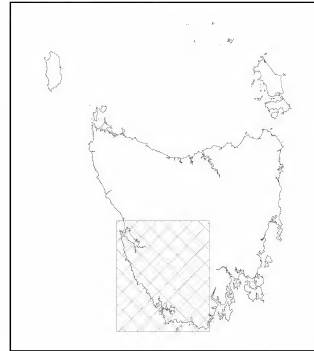
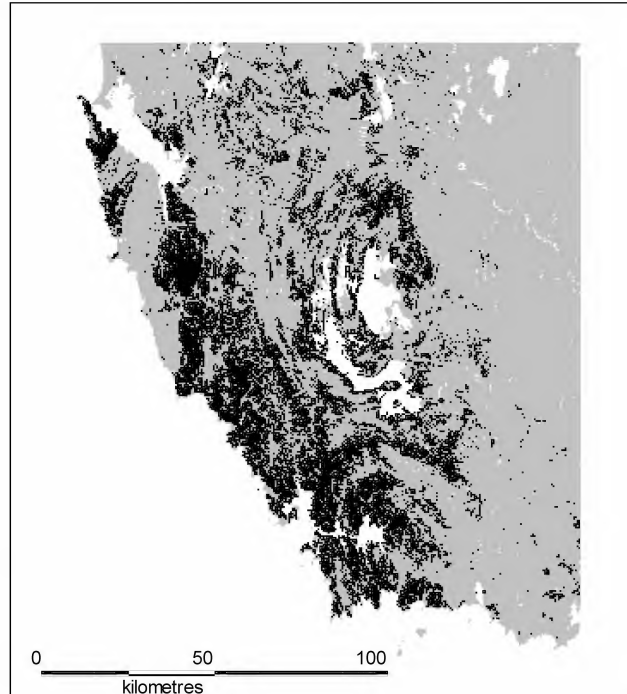


Figure 1. Extent of simulated study area (hatched) in southwest Tasmania. Buttongrass moorland communities are shaded black.



Results

The relationships between each of the three prescribed burn treatment parameters and the three fire effects simulated are summarised in figures 3–5. To illustrate the full range of results, each figure shows only the simulated combination of treatments (treatment level, block size and spatial pattern of blocks) that resulted in the least and greatest effect on each fire parameter.

When at least 5% of the Buttongrass moorlands were prescribe-burned annually, the number of unplanned fires declined in an approximately linear fashion with increasing treatment level (Fig. 3). Statistical analysis demonstrated that an ordered spatial pattern of prescribed burns was more effective than a random one at further reducing the number of unplanned fires only at treatment levels of at least 10%, and that there was no significant effect of prescribed burn block size on reducing the number of unplanned fires for any treatment level.

In simulations for annual prescribed burn treatment levels of at least 2%, fire sizes decreased with increasing treatment level (Fig. 4). Statistical analysis demonstrated further smaller reductions in fire sizes with both ordered

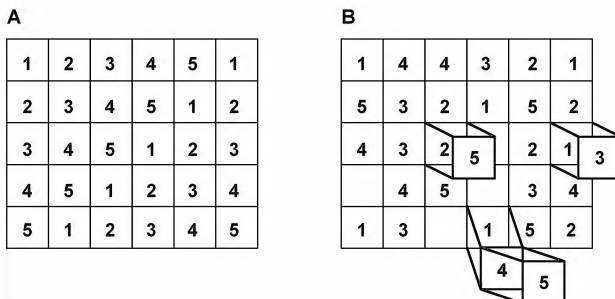


Figure 2. Schematic diagram depicting simulated spatial patterns of prescribed burning blocks. Blocks with the same number are burned in the same year using either (a) an ordered or (b) a random pattern.

spatial patterns and small block sizes ('fine scale fuel mosaics') when at least 10% of the Buttongrass moorlands were annually prescribe-burned.

The mean annual area burned by unplanned fires exhibited an approximate negative exponential decline with treatment levels of at least 2% (Fig. 5). Treatment level had the most significant effect on areas burned, with both ordered spatial patterns of blocks and 'fine scale fuel mosaics' further reducing the mean annual areas burned by unplanned fires.

Discussion and conclusion

A variety of relationships exist between prescribed burning parameters and fire effects in southwest Tasmania. The simulations suggest that the annual treatment level had the greatest effect in reducing each of the three fire effects (number and size of unplanned fires, and the mean annual area burned), with critical thresholds needed before any statistically significant variations in the fire effects were observed. Spatial pattern was shown to be important only after critical thresholds in treatment level (10%) had been reached, with ordered spatial patterns shown to be more effective. 'Fine scale fuel mosaics' (small prescribed burn block sizes) were only effective in further reducing unplanned fire sizes, and hence mean annual areas burned, at treatment levels of greater than 10%. Overall, the results provide some limited support for the hypothesis that 'fine scale fuel mosaics' may enhance the reduction in fire incidence and propagation, provided the net proportion of low fuel in the landscape is relatively high (i.e. the annual prescribed burning rate is also high).

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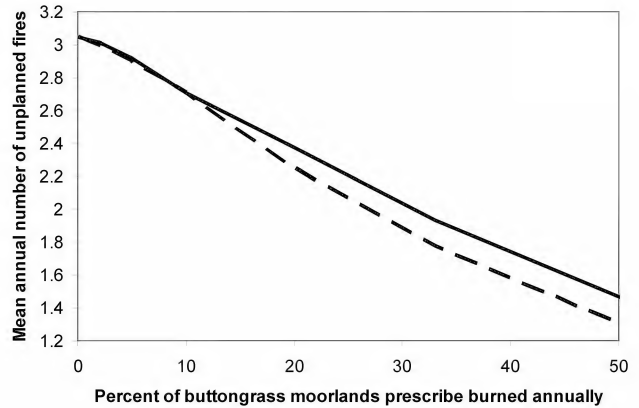


Figure 3. The mean annual number of unplanned fires for random (solid line) and ordered (broken line) spatial patterns of prescribed burn blocks.

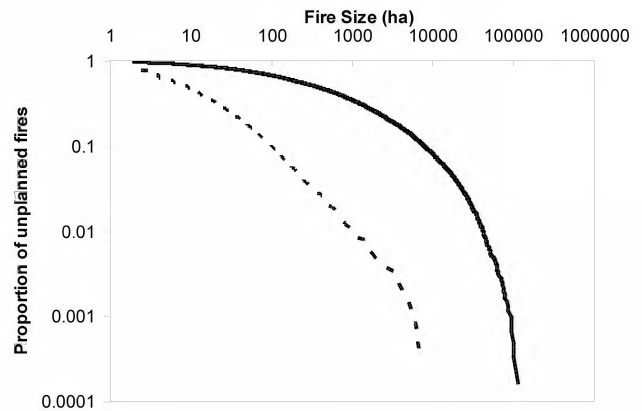


Figure 4. Range of fire size distributions shown as the proportion of all unplanned fires as large as or larger than a given size. The largest unplanned fire sizes (solid line) resulted from no treatment, and the smallest (broken line) resulted from a 50% treatment level, ordered spatial pattern and 1 hectare treatment unit size.

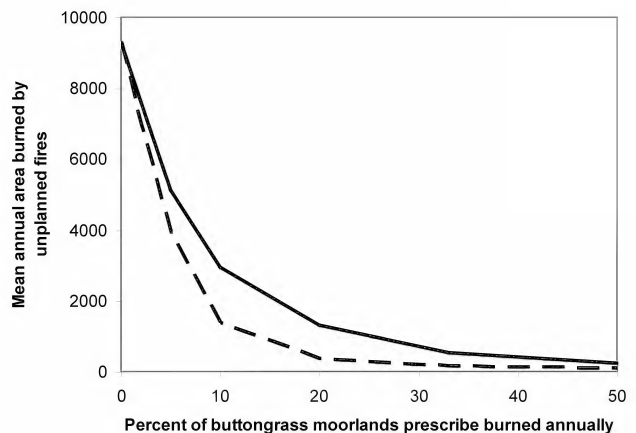


Figure 5. Range of mean annual areas burned by unplanned fires. The smallest areas burned by unplanned fires for a given treatment level were when prescribed burn blocks were 1 hectare and arranged in an ordered spatial pattern (broken line). The largest mean annual areas burned for a given treatment level were when prescribed burn blocks were 4000 hectare and arranged in a random spatial pattern (solid line).

Conservation seed collections from plants in Tasmanian Buttongrass moorlands

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There has been little work done on the seasonality, viability and germination of seed from plants that grow in Tasmanian Buttongrass moorland. The highly acidic and nutrient deficient nature of the moorland environment means that plants growing there may have specialised reproductive adaptations. The current Tasmanian SeedSafe project has the scope to make some interesting observations on the seed biology of moorland plants. Only a few Buttongrass moorland species have been collected, cleaned, tested and banked at the Tasmanian Seed Conservation Centre. However there are well over 100 species from these communities being targeted for collection and testing over the next two years.

One example from work carried out so far by our project is the case of Buttongrass itself. Buttongrass (*Gymnoschoenus sphaerocephalus*) is a large tussock-forming sedge. A slow growing, pyrogenic (fire-stimulated) resprouter, this sedge is likely to be very long-lived. Attempts to collect seed from Buttongrass have not yet been successful. In March 2006, 30 g (dry weight) of seedhead material was collected from approximately 80 individuals. The collection site was at Melaleuca in the southwest corner of Tasmania, home to a large, healthy Buttongrass population. This collection yielded only 200 seeds. A cut test from a sample of 50 seeds suggested that only 100 of these were actually good, the rest being empty, infested or immature.

Subsequent inspections of Buttongrass from other areas in Tasmania have yielded similar low seed set levels. Considering the dense nature of the inflorescence, with many individual flowers in a dense head, this seed yield (effectively 1-2 seeds per head) is surprisingly low. Given the oligotrophic (nutrient-poor) nature of the habitat and Buttongrass' tendency to burn and re-sprout post fire, it is possible that seed set might be influenced by fire. It would be interesting to sample seedheads the season after a fire event to see whether fecundity is improved.

Low fecundity (as indicated by seed set) poses a significant challenge for the collection of Buttongrass seed for research and conservation. The standard recommendation for the size of a seed collection for conservation purposes is around 10,000 viable seeds. To achieve this, based on the seed set seen to date, around 30 kg (dry weight) of seedheads, or alternatively over 80,000 seedheads, would need to be collected.

Another aspect of effective seed conservation is the storability of the seed. Ongoing studies on comparative

longevity at the Millennium Seed Bank (UK) suggest that the seeds of species growing in cooler wetter climates and with smaller embryos (the majority of Cyperaceae) are shorter lived than those from other environments. This would seem to lend credence to the speculation that Buttongrass might produce seeds in quantity after a disturbance event rather than slowly develop a soil seed bank over several seasons prior to a fire event.

Observations on species of Restionaceae (such as *Winifredia sola*, *Eurychorda complanata* and *Baloskion australe*) that grow in Buttongrass moorlands have revealed a similarly low level of seed set. As a group Restionaceae have been observed to develop mature seed from approximately 50% of flowers in Western Australian species (Meney *et al.* 1999). This is far in excess of what has been observed in the Tasmanian moorland species, although once again the majority of these species re-sprout after fire and it would be interesting to observe the seed set in the season post-fire, when there is a spike in nutrient levels and opportunities for seedling recruitment exist.

Plants in several other families present in the Buttongrass moorland community do produce large quantities of seed from year to year (as in Asteraceae, Xyridaceae, Epacridaceae, Centrolepidaceae), or employ serotiny (having a canopy-stored seedback, as in Myrtaceae and some Proteaceae). It is anticipated that many of the species in these families will show only low level dormancy, and thus be adapted to fairly quick germination post dispersal. However, there will be exceptions. For example, germination testing at the Millennium Seed Bank (U.K.) of Tasmanian *Xyris* collections has shown *X. operculata* to germinate readily at a broad range of temperatures (achieving greater than 75% germination at 15-25°C). In contrast, *X. muelleri* displays some type of dormancy, achieving a maximum of 4% germination over the same range of temperatures.

There is much potential for further observations on seed set and dormancy and other aspects of seed biology of Tasmanian Buttongrass moorland plant species that are targeted for seed collecting in the next few years.

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The conservation value and reservation status of the Tasmanian Buttongrass moorland vascular plant flora

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Unique environment

The flora of Tasmanian Buttongrass moorlands is diverse and well adapted to harsh conditions, such as extremely low nutrient availability, water-logging and frequent fire. Some of the physiological adaptations that enable plants that live in Buttongrass moorland to survive these conditions include a high degree of scleromorphy, rhizomatous habit and the ability to regenerate vegetatively. *Gymnoschoenus sphaerocephalus* (Buttongrass) and many other Buttongrass moorland species have high silica levels and the lowest recorded phosphorus levels in their foliage of any plant species, and plants can re-absorb phosphorus from their leaves (Maclean 1978, Bowman *et al.* 1986). Silica impedes litter decomposition but does not inhibit flammability (Mutch and Philpot 1970).

The unique alkaline pans which only occur within Tasmanian Buttongrass moorlands provide an environmental niche for species such as *Milligania johnstonii* (Short Leaf Milligania) and *Isoetes* sp. nova 'Maxwell River' (Limestone Quillwort), which are listed as rare on the Tasmanian *Threatened Species Protection Act 1995* (TSPA). Other Tasmanian endemic species in this habitat include *Hydatella filamentosa* (Tasmanian Watertuft), *Schoenus biglumis* (Westcoast Bogsedge) and *Oreobolus tholicarpus* (Redsheath Cushionsedge).

A richness of species

There are more than 272 vascular plant species recorded for Tasmanian Buttongrass communities, spanning more than 50 families (Jarman *et al.* 1988, Balmer and Storey unpublished data). Of these, 209 species from 50 families typically occur in Buttongrass moorlands. Only five families have more than ten species that typically occur in Buttongrass moorlands: Cyperaceae (23 spp.), Epacridaceae (18 spp.), Myrtaceae (16 spp.), Restionaceae (12 spp.) and Poaceae (11 spp.). Graminoid species make up 38% of native plant species recorded, woody species 39%, forbs 22%, and ferns and their allies just 3%.

Restricted endemic species

There is a high level of endemism within Buttongrass moorland communities with 34% (69 spp.) of vascular plants being endemic to Tasmania and an additional 2% (4 spp.) being endemic to Australia. Tasmanian endemic species almost wholly restricted to western Tasmanian Buttongrass moorlands include *Boronia elisabethiae*

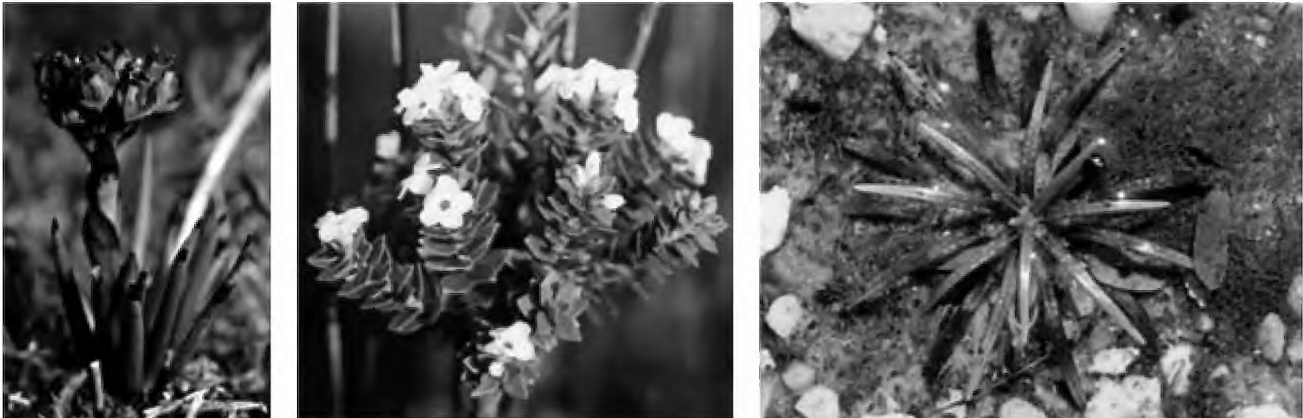
(Creeping Boronia), *Epacris corymbiflora* (Buttongrass Heath), *Gaimardia amblyphylla* (Bluntleaf Pincushion), *Haemodorum distichophyllum* (Bloodroot), *Oschatzia saxifraga* (False Saxifrage) and *Sprengelia distichophylla* (Tiny Swampheath). Tasmanian endemic species with restricted distributions in eastern Tasmania include *Prasophyllum amoenum* (Dainty Leek-orchid), *Chordifex monocephalus* (Smooth Buttonrush), *Euphrasia gibbsiae* subsp. *psilantherea* (Swamp Eyebright) and *Boronia pilosa* subsp. *tasmanensis* (Tasman Hairy Boronia). *Epacris curtisiae* (Northwest Heath) is a Tasmanian endemic species restricted to the northwest of Tasmania.



Green Mountain Lily *Campynema lineare*, a primitive plant of Buttongrass moorland. Photo: Tim Rudman

Rare and/or threatened flora

There are six species listed under the *TSPA* and/or the Australian *Environment Protection and Biodiversity Conservation Act 1999* (EPBCA) that are known to occur within Buttongrass moorlands. *Epacris curtisiae*, *Isoetes* sp. nova 'Maxwell River', *Milligania johnstonii*, *Comesperma defoliatum* (Leafless Milkwort) and *Persoonia moscalii* (Creeping Geebung), are listed under the *TSPA* as rare. One species, *Centrolepis pedderensis* (Pedder Bristlewort), is listed under the EPBCA as endangered and under the *TSPA* as vulnerable. *Centrolepis pedderensis* was once common on the sandy shores of Lake Pedder in the State's southwest until the lake was flooded following the construction of the Huon-Serpentine impoundment in 1972. It is now only known from two small populations of lacustrine habitat in the State's southwest with less than fifty individuals remaining.



Left to right: Bloodroot *Haemodorum distichophyllum*. Endemic to southwest Tasmania. Photo: Threatened Species Unit; Northwest Heath *Epacris curtisiae*. A Tasmanian endemic restricted to the northwest. Photo: R. Schahinger; Limestone Quillwort *Isoetes* sp. 'Maxwell River'. An undescribed threatened species that is a southwest endemic. Photo: M. Garrett

Five species known to occur in Buttongrass moorlands are currently considered to be uncommon (Flora Advisory Committee 1994). These are *Caesia alpina* (Alpine Grasslily), *Boronia rhomboidea* (Broadleaf Boronia), *Schoenus biglumis* (Westcoast Bogsedge), *Carex polyantha* (River Sedge) and *Poa clelandii* (Purplish Tussockgrass). The uncommon status of the native vascular flora in Tasmanian is currently being reassessed with new survey data from 1995 to 2007. Preliminary results show that *Carex polyantha* and *Poa clelandii* are probably not uncommon.

Primitive flora

Some species within Buttongrass moorlands have ancient origins. The world's most primitive lily *Campynema lineare* (Green Mountain Lily) occurs in Buttongrass moorland as well as the alpine moorlands of southwest Tasmania. *Agastachys odorata* (Fragrant Candlebush) and *Banksia marginata* (Silver Banksia) are important components of some Buttongrass communities and are primitive genera of the Gondwanan family Proteaceae (Hoot and Douglas 1998). *Agastachys odorata* is a fragrant shrub that is able to regenerate after fire by vegetative means, producing suckers that emerge at intervals along long surface roots. This species is rapidly killed by *Phytophthora cinnamomi*.

Genera showing some of the most primitive morphological and DNA traits within the Gondwanan plant family Restionaceae (Cord-rushes) include *Calorophus* and *Sporadanthus*, which are important components of Tasmanian Buttongrass moorlands. Morphological data suggests that *Empodisma* and *Winifredia*, the monotypic genus represented by *Winifredia sola* (Southwest Cordrush), an endemic of southwest Tasmania, are basal members of the Australian *Leptocarpus* clade (Linder *et al.* 2000). However the DNA research suggests that, rather than being primitive ancestors of the *Leptocarpus* group of genera, they form a separate unrelated group (Briggs *et al.* 2000). Together with the roots of sedges, the roots of the Cord-rushes are likely to contribute most to the soil organic content.

Reservation status

The majority of species of Buttongrass moorlands are very well reserved as this vegetation type is one of most extensively reserved communities in Tasmania. Of those vascular plant species that typically occur within Buttongrass moorlands, ten species have their total known distribution within reserves including three listed species, *Milliganii johnstonii*, *Persoonia moscalii* and *Centrolepis pedderensis*. The majority of typical species are reserved in at least half of the bioregions in which they occur and no species are unreserved (Lawrence *et al.* in press). However, the heath species *Epacris curtisiae* may not be adequately reserved, being a rare species that does not occur within any dedicated formal reserve and is thus not protected from mining.

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Fire and *Sphagnum* in Tasmania

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Introduction

Sphagnum peatlands are a specialised peatland type in Australia, with a limited distribution, generally increasing in occurrence in the landscape from north to south and with increasing elevation (Whinam and Hope 2005). In New South Wales and Victoria, some *Sphagnum* communities are protected by legislation as threatened communities. In Tasmania, *Sphagnum* peatlands are identified as a priority non-forest community.

In Tasmania *Sphagnum* moss often occurs along drainage lines and around the margins of montane Buttongrass moorlands. Buttongrass moorlands are a fire-promoting vegetation characterised by the fire-tolerant sedge *Gymnoschoenus sphaerocephalus* (Buttongrass). When fuel reduction burns are undertaken, fire often extends into the margins of fire-sensitive *Sphagnum* peatlands (Whinam *et al.* 2003). This can cause death of the *Sphagnum* moss, burning of the peat and expansion of tussocks of Buttongrass moorland into the *Sphagnum* peatland, increasing the flammability of the community. In the light of predicted changes in weather patterns associated with climate change, an increase in intensity and/or frequency of fire events is likely, with consequent implications for the survival and extent of *Sphagnum* peatlands (Hope *et al.* 2005).

This study investigates which peatland species are favoured and which disadvantaged by fire, and whether it is possible to maximise the effectiveness of fuel reduction burns in Buttongrass moorlands while minimising the impacts of fire on adjacent *Sphagnum* peatlands.

Materials and methods

Navarre Plains is a large, poorly drained, flat moorland at 740 m elevation in central Tasmania, on the edge of the Tasmanian Wilderness World Heritage Area. The Navarre Plains has a history of repeat arson, originating from the Lyell Highway. Patches of *Sphagnum* moss occur throughout the plains, but appear to be remnants, at the margins of the Buttongrass moorlands or along drainage lines. Ten contiguous 0.25 m² quadrats were established on burnt *Sphagnum* peatland, the day after a deliberately-lit hot fire in November 1990. Remains of *Sphagnum* moss were visible across the transect, but the fire did not burn into the peat. Conditions were dry at the time, with the Soil Dryness Index at Lake St Clair being 21 mm. Ten control plots were established in an adjacent unburnt remnant, but there was no pre-fire data. Data were collected for ten visits to the burnt transect and seven visits to the unburnt transect, between 1990 and 2007 (see Figure 2 for the dates of each visit). Species percentage

cover data from the plots on each transect were averaged for each visit and the averaged data ordinated using a non-metric multi-dimensional scaling technique.

Results

In an ordination, points closer together are more similar than points further apart. The ordination (Fig. 1) shows distinct differences between the vegetation cover of burnt and unburnt plots with the unburnt transect changing little over time compared with the burnt transect. There was a relatively rapid increase in vegetation cover and change in vegetation structure on the burnt plots post-fire. Four years after the fire, graminoid cover (dominated by Buttongrass, *Empodisma minus* and *Lepidosperma filiforme*) reached 60% in the burnt plots, with *Sphagnum cristatum* at less than 7% cover on average (Fig. 2b). There was an immediate explosion of *Celmisia asteliifolia* seedlings post-fire, but this was not sustained at 4 years post-fire. In the unburnt area, *Sphagnum* cover was maintained at 70% (Fig. 2a), but there was an initial decline in vigour post-fire. Several *G. sphaerocephalus* seedlings have germinated in the unburnt *Sphagnum* hummocks since the fire in 1990, which may potentially lead to an increased pyrogenicity of the site over time.

Seventeen years post-fire Buttongrass had reached 83% cover on the burnt plots, with *Sphagnum* <5% (Fig. 2b).

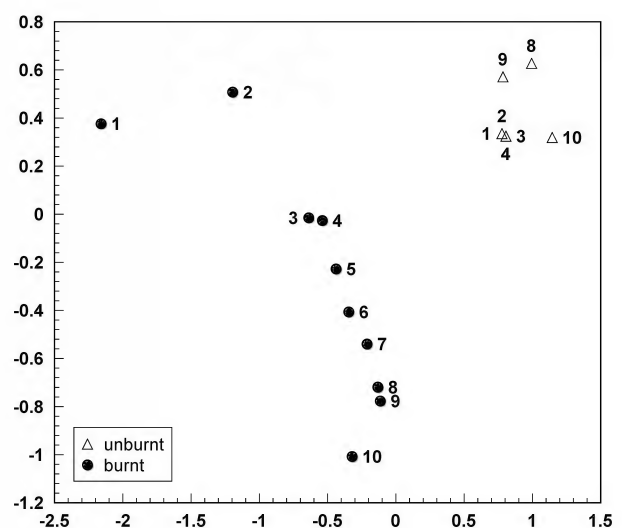


Figure 1. Ordination of species percentage cover averaged for each transect at each visit. Numbers refer to the visits. Visit 1= Nov 1990, 2=Mar '91, 3=Nov '91, 4=Mar '92, 5=Mar '93, 6=Nov '93, 7=Dec '94, 8=Dec '97, 9=Mar '00, 10=Feb '07.

A total of 17 vascular species was recorded over the 26 years of monitoring, as well as fungi, lichens and mosses (predominantly *Polytrichum juniperinum*). Species richness in the unburnt plots has remained steady, compared with an initial increase in species richness in the burnt plots until 1993, but by 1994 species richness had declined (Fig. 3). Buttongrass has provided a thick ground layer of thatch that has made re-colonisation by other species – especially *Sphagnum* – physically impossible.

Discussion

Fire (repeated or very hot burn) affects the vegetation structure and benefits Buttongrass to the detriment of *Sphagnum* moss. This indicates that there will need to be further collaboration between agencies to ensure that fuel reduction burns minimise impacts on *Sphagnum* peatlands. Alternative methods of ignition and fire control should be investigated, such as burning away from the margins of *Sphagnum* moss into the moorland. Observations suggest that burning from the centre of the moorlands towards the margins results in the mossbeds being exposed to hotter fires. An alternate prescription, and one that has been used previously, is to slash around *Sphagnum* moss, although this is very labour intensive. Timing of the burns is also likely to be important. Peat is likely to be at its most saturated during spring, suggesting that this time might be preferable to undertake fuel reduction burns, minimising the risk of peat fires. However, the area is Wedge-tailed Eagle habitat and spring burning is considered a risk to this endangered species.

The impetus to protect *Sphagnum* peatlands throughout Australia from increased fire frequency and/or intensity is likely to increase, as evidenced by the large scale destruction of *Sphagnum* peatlands in the 2003 bushfires in Namadgi (ACT) and Kosciuszko (NSW) National Parks. Ecologists, land managers and fire managers will need to continue working together to trial different techniques and monitor the results to ensure a balance between satisfactory fuel reduction in a pyrogenic peatland, while minimising the impacts to the *Sphagnum* moss that occurs around the margins and drainage lines of Buttongrass moorlands.

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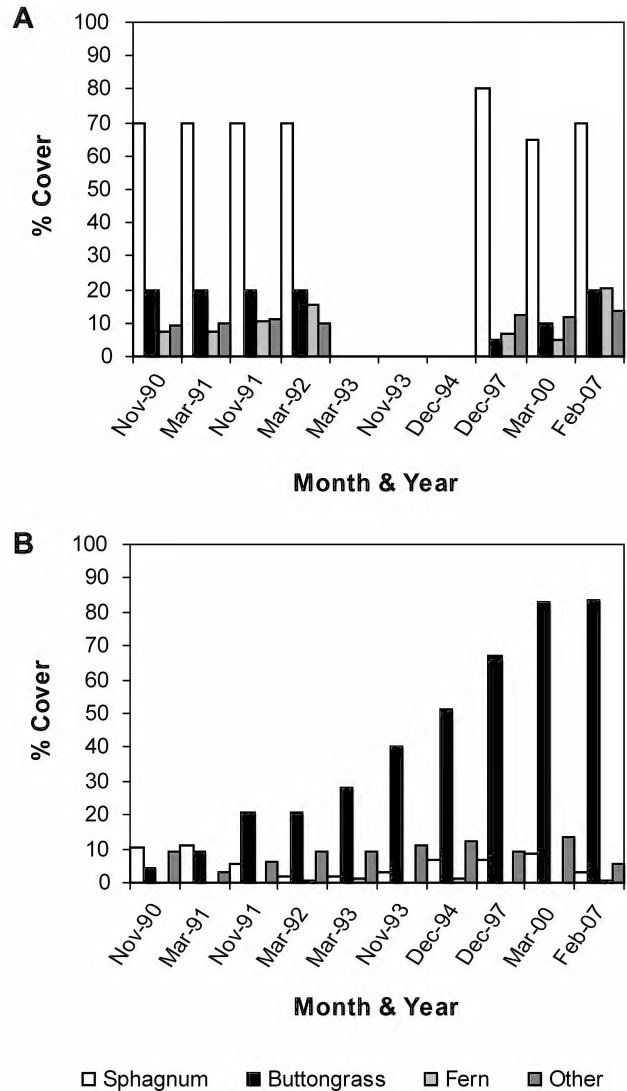


Figure 2. Average percentage cover of life-forms on the (a) unburnt and b) burnt transect over time.

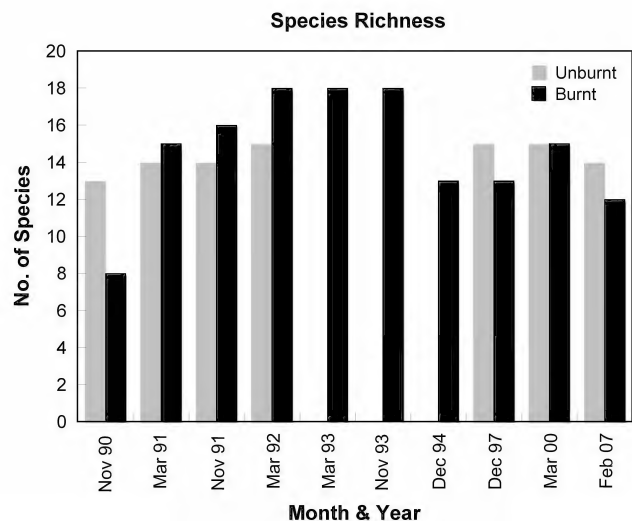


Figure 3. Species richness of burnt vs unburnt transects over time.

How do bryophytes respond to fire in Buttongrass moorland?

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What is a bryophyte?

Mosses, hornworts and liverworts, together known as 'bryophytes', are small plants that lack the internal water conduction system of other, usually larger, plants ('vascular plants'). Unlike most plants, bryophytes are poikilohydric – photosynthesizing and growing during moist periods and suspending metabolism during times of drought (Proctor 2000). This means that bryophytes are able to colonise niches where conditions are too harsh for vascular plants, such as exposed cliff faces, desert rangelands, and polar areas (Proctor 2000).

Why study bryophytes in Buttongrass moorland?

Buttongrass moorland is a pyrogenic vegetation type—one that contains species which exhibit characteristics ensuring flammability and features which permit it to survive and/or regenerate after fire (Brown 1999). While there are no published studies examining change in bryophytes following fire in Buttongrass moorland, studies from other environments, both in Australia and overseas, have found that bryophytes play a significant role in the re-establishment of vegetation after fire. Bryophytes known as the 'fire mosses' (*Funaria*, *Ceratodon*, and the liverwort *Marchantia*) move in and colonise after fire, and it is purported that these mosses lower the soil temperature, increase soil moisture retention, and alter nutrient flows, thereby creating a more favourable environment for other plants (O'Neill 2000). One of the most important roles of fire mosses is in the stabilisation of soil. While the post-fire environment is still too harsh for other plants, the fire mosses are able to grow and spread, anchoring the soil and reducing soil erosion.

The study area and method

My study focused on two areas in Tasmania: the Buttongrass moorlands surrounding Lake Pedder and Lake St. Clair. Forty-four sites were selected and surveyed for bryophytes, 19 at Lake Pedder and 25 at Lake St. Clair. These sites differed in Buttongrass age, with time since last fire ranging from six months to 67 years. At each of the 44 sites, the variables Buttongrass tussock height, average tussock diameter and average tussock interspace were measured. Five 2 m x 2 m quadrats were then randomly located and surveyed for bryophytes (220 quadrats in total). The amount of bare ground, percent of the quadrat that was submerged, and the percent of vascular plants other than Buttongrass were also noted for each quadrat.

Results

A total of 44 bryophyte species were found from the 220 quadrats surveyed, with the species being equally divided between mosses and liverworts. *Sphagnum*, a moss often thought to be common in Buttongrass moorland, was only found at 12 sites around Lake St. Clair. The 'Fire Mosses' were found only four times, and this was in very small patches numbering no more than five individual stems.

Buttongrass character and bryophyte richness

It was found that fire influenced the character of the Buttongrass tussocks, with fire reducing the height and width of tussocks and causing them to be further apart. Approximately ten years after being burned the Buttongrass tussocks have expanded again, closing the gaps between the tussocks and lowering the amount of ground available for bryophyte colonisation. However, once the tussocks begin to be replaced through succession (with shrubby vascular plant species infiltrating the once tight matrix of Buttongrass), the tussocks became further apart. When the bryophyte species found at each site were averaged and graphed against time since last fire, a general pattern was seen, with average bryophyte richness falling in the intermediate time since fire ages and rising in the oldest Buttongrass stands (Fig. 1). That the greatest bryophyte species richness was found in the oldest sites is assumed to be because, as the Buttongrass moorland ages and the Buttongrass is penetrated by vascular plants, the tussocks are opened up and space is provided for bryophytes to colonise.

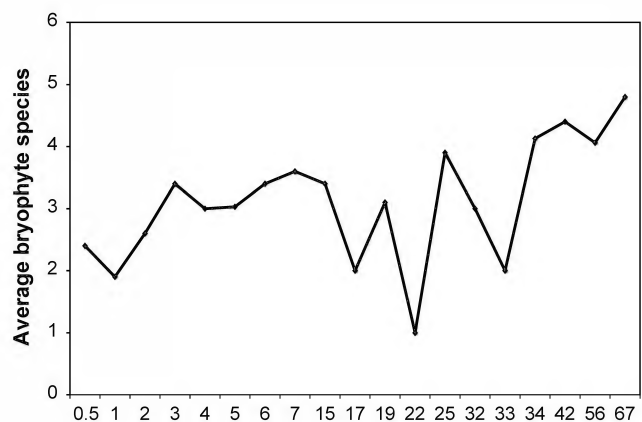


Figure 1. Average bryophyte species richness according to time since last fire.

Bryophyte richness and composition and time since fire

The time since fire was found to significantly affect bryophyte species richness. Further analysis discovered that this significant result was due to changing abundance of liverworts, and the liverworts of Lake Pedder, to be more precise.

Time since the last fire was also found to significantly influence bryophyte species composition, although not strongly. As with bryophyte richness, when dividing bryophyte species into 'moss' or 'liverwort', only liverwort composition was being influenced by time since last fire, although the liverworts of Lake Pedder and Lake St. Clair were both contributing to this relationship. Time since fire was also significantly affecting the moss species of Lake Pedder. However, the moss species of Lake St. Clair remained unaffected.

Conclusion

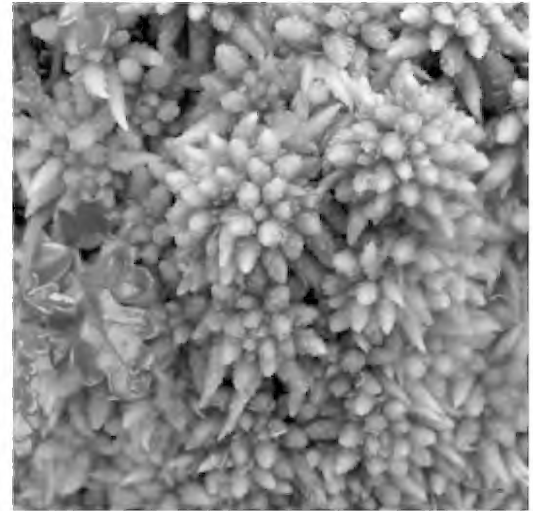
It can be concluded from the results described above that there is a relationship between liverworts and fire, although the relationship cannot be easily defined. Moss species do not appear to be affected by time since fire. This is possibly because liverworts are known to prefer wetter environments and are more reliant on water than mosses. This has implications for fire management as liverworts need a mosaic of burning ages.

It also seems that the bryophytes of Lake Pedder and Lake St. Clair react differently to time since fire, with species at Lake Pedder being more influenced by fire than those at Lake St. Clair. This is possibly due to the difference in fertility, rainfall and altitude between the two areas, with the lower fertility of Lake Pedder resulting in a species composition that is more sensitive to fire.

Finally, Buttongrass moorland does not display the distinctive pattern of colonisation by fire mosses after fire that is exhibited in Tasmanian wet forests and throughout the world.

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Left: Fruiting *Pleurophascum grandiglobum*, a moss only found in Buttongrass moorland.
Right: *Sphagnum cristatum*, Lake St. Clair. Photos: Mikayla Jones

Buttongrass

Adrienne Eberhard

Your name suggests something prim, properly
fastened to the soil, trim and tidy, tiny
and missable, but you flounder your skirts in mud,
bouffant as an emu, all swag
and tussock, scraggy as a ground-dweller's nest,
and flag the clouds with your bobbing antennae
like extra-terrestrial eyes or fireflies
with their lights turned out.
Rustling wantonly, you shimmy
your long, thin stems, brown
as rattan blinds, swaying like stilt walkers,
the first drops of rain sufficient
to set you off, nodding your heads,
those tightly-stuffed pincushions that dry
and shrivel to a brace of cloves, to miniature,
mummified dandelion clocks, dark
as the bog queen's leathery skin,
that in a vase are shooting stars
jostling for the perfect trajectory.

Drawing by Richard Hale

Lichens: an overlooked Lilliput in Tasmania's Buttongrass moorlands

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Introduction

Lichens are very prominent in some Buttongrass moorland communities, and may make up the dominant ground cover. However, they often go largely unnoticed by visitors who traverse this vegetation, typically on their way to somewhere else (such as some lofty peak).

Kantvilas & Jarman (1988) recorded 89 species of lichens from Tasmanian Buttongrass moorlands and discussed their distribution and ecology. Numerous additional species have been recorded since, and several new taxa have been described, including the endemic Tasmanian species *Cladia deformis* and *C. dumicola* (Kantvilas & Elix 1999), *Santessoniella rugosa* (Henssen & Kantvilas 2000) and the monotypic genus *Siphulella* (Kantvilas *et al.* 1992).

Lichens are rarely considered when management regimes for Buttongrass moorland are being defined. The aim of this paper is to describe some of the major lichen habitats in Tasmania's Buttongrass moorland and to draw the reader's attention to this often-overlooked lilliputian realm.

The lichen flora of moorland

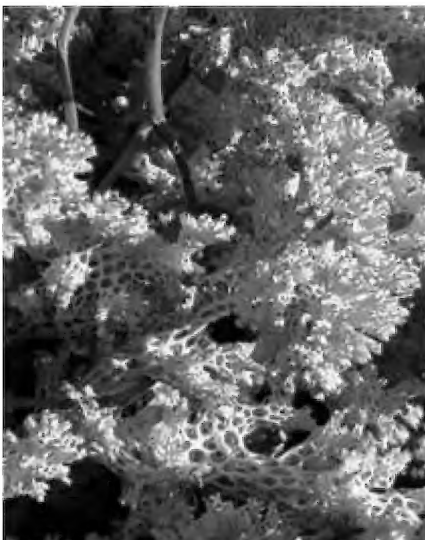
Despite its prominence, there is probably no Buttongrass moorland lichen flora *per se*. The lichen flora of moorland is essentially a mixture of species that are either ubiquitous across a whole range of vegetation types or are found in a much better state of development elsewhere, especially

in adjacent alpine or subalpine heathland, cool temperate rainforest or eucalypt forest. Furthermore, these other vegetation types are typically less seral, less dynamic and more stable ecologically. Thus Buttongrass moorland lichens are usually either: (1) rather weedy species able to cope with disturbance such as fire and living in dynamic conditions where succession occurs quickly and involves often rapid regrowth of vascular plants and concomitant changes in microhabitats, or (2) they are species able to persist in tiny, highly localised refugia in the face of such disturbance and successional change.

Major habitats for lichens

Peat and soil

Here lichens co-exist with vascular plants, literally on the same turf. The major species in this habitat typically belong to the genera *Cladonia* and *Cladia* (Fig. 1), and often form conspicuous clumps and swards. Also prominent, especially in the South-West, are *Siphula*, with chalky lobes anchored to the soil by root-like rhizines, and *Micarea*, which encrusts the soil surface. Such lichens have an obvious role to play in soil stabilisation, akin to that of the cryptogamic soil crusts found in arid rangelands. Although lichens prefer well-drained, well-lit habitats, such as peat banks, the tops of rotting hummocks or gaps between sparse graminoids and shrubs, a few, such as *Siphula jamesii* and *Cladia moniliformis* can be abundant in or around shallow puddles.



Left: Figure 1. *Cladia retipora* (Coral Lichen), a common species on peat and soil in Buttongrass moorland.
Right: Figure 2. Rock outcrops are critical islands of lichen diversity in Buttongrass moorland, supporting a suite of foliose, fruticose and crustose species. Photos: Jean Jarman

Rocks and pebbles

Large rock outcrops are a particularly diverse and important habitat, with common lichens being tufts of *Usnea*, foliose species of the family Parmeliaceae and many crustose lichens such as *Ramboldia petraeoides* (Fig. 2). Birds use these rocks for perching, and their role in dispersing lichen propagules, altering pH and importing nutrients, although uninvestigated, is likely to be very significant. The rocks also offer some fire protection. Often they support remnant vascular plant vegetation more typical of, for example, rainforest, such as shrubby individuals of rainforest trees and remnant rainforest epiphytes such as *Prionotes* or filmy ferns. In the same way, many normally epiphytic rainforest lichens, such as species of *Bunodophoron* and *Pseudocyphellaria*, may also be present, growing directly on the rocks, in peat filled crevices or on the shrubs. These rocks are critical islands of diversity in an otherwise rather bland and uniform landscape. Exposed pebbles are also typically colonised by lichens, especially by *Paraporpidia leptocarpa*, visible only as lines of tiny, black fruiting bodies etching the pebble's surface.

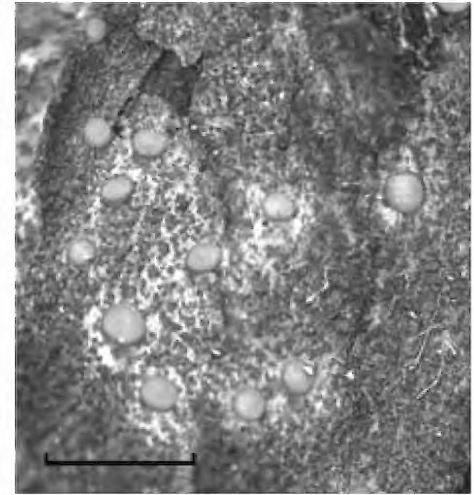
Wood and bark

Epiphytic lichens are generally uncommon because trees and shrubs in moorland rarely attain large enough size to offer the diversity of habitats necessary for a complex epiphytic flora. However, the red-fruited *Pyrrhospora laeta* and the yellowish *Tasmidella variabilis* colonise the youngest twigs (Fig. 3). Scrubby copses within moorland offer some larger hosts although, in general, the dominant eucalypts and the flaky barked *Leptospermum* and *Melaleuca* are very poor hosts for lichens. Scattered, emergent, large shrubs of *Banksia*, *Hakea* and *Allocasuarina* may support quite rich floras, dominated by *Usnea*, *Hypogymnia tasmanica* and crustose species. Dead or charred wood will support *Hypocenomyce australis* and *Ramboldia stuartii*.

Distribution

The distribution of lichens in Buttongrass moorland reflects the distribution of the major higher plant community groups, in particular the distinction between the blanket bogs of the south and west, versus the moorlands of the centre and east of the State.

Like the vascular plants, most lichens have a predominantly Southern Hemisphere distribution. However, a significant proportion of species, maybe around 25%, also occur in Northern Hemisphere moorlands, or have close relatives there. To go on a lichen ramble in the Yorkshire moors can certainly kindle a sense of familiarity and nostalgia for Tasmania, with identical or at least similar species growing in the same habitats.



Left: Figure 3. The Tasmanian endemic crustose lichen, *Tasmidella variabilis*, visible as tiny, black, speck-like fruiting bodies, is one of the first colonisers of twigs in Buttongrass moorland. Right: Figure 4. *Santessoniella rugosa*, a very rare and un-reserved Tasmanian endemic lichen, occurring in wet scrub fringing Buttongrass moorland. Scale = 2 mm. Photos: Jean Jarman

Conservation and management

The widespread nature of most Buttongrass moorland lichens means that conservation of individual species is usually adequately addressed through the conservation of vascular plant communities. However, a notable exception is the endemic *Santessoniella rugosa* (Fig. 4), known from only a single population in wet *Melaleuca* scrub fringing moorland. This species is very rare, unreserved and at very high risk, growing in rather seral vegetation in a landscape subject to fire. There may well be other, as yet overlooked species with a similar distribution pattern.

The long-term impact of fire in Tasmania's Buttongrass moorland is difficult to predict. Lichens are clearly very fire-sensitive. Fire kills them and, perhaps equally importantly, potentially removes what they grow on: peat, wood and the bark of older shrubs. However, the abundance of lichens in at least some communities, although often extremely localised, is proof of the potential resilience of some species despite burning. Of critical importance when managing Buttongrass moorlands is to appreciate that there are lichens out there and to understand what habitats they occupy. There are many different species involved, and just because one or two recover quickly after fire, it doesn't mean they all do. It is also critical to maintain a diversity of vegetation types, habitats and fire regimes, to ensure that refugia and suitable lichen niches are maintained.

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Buttongrass moorland fauna

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As habitat, Buttongrass moorland is a challenging place for animals to live. The peat is highly acidic (pH 3.5-4.5) and the soil surface may be dry, cracked and hard in summer and inundated with water in winter. Hard-leaved plants that are low in nutrient value dominate the vegetation; indeed, Buttongrass (*Gymnoschoenus sphaerocephalus*) itself has the lowest recorded phosphorous levels in its foliage of any plant species. Buttongrass moorland vegetation is highly flammable and was probably frequently burnt by Aborigines prior to European settlement. The lack of structural and floristic diversity of the vegetation further limits the habitat for fauna. As a result the diversity and abundance of fauna in this habitat is relatively low yet it has its own characteristic elements.

Vertebrate fauna

Few of Tasmania's vertebrate animals are known to spend their entire life-cycle within Buttongrass moorland (Table 1) and most of these species also occur in other habitats. Buttongrass moorland is the primary habitat in Tasmania for six species of vertebrate, the Broad-toothed Mouse (*Mastacomys fuscus*), the Ground Parrot (*Pezoporus wallicus*), the Striated Fieldwren (*Calamanthus fuliginosus*), the Southern Emu-wren (*Stipiturus malachurus*), the endemic Tasmanian Tree Frog (*Litoria burrowsae*) and the endemic Swamp Galaxias (*Galaxias parvus*). In addition, the endangered, migratory Orange-bellied Parrot (*Neophema chrysogaster*) is dependent on Buttongrass moorland for feeding during its breeding season and nests in adjacent forest vegetation. Buttongrass moorland is also the stronghold for the Swamp Antechinus (*Antechinus minimus*) in Australia although it does occur in other habitats, notably coastal heathland. The ground parrot is a particularly remarkable inhabitant of these moorlands, being one of only three ground-dwelling parrots in the world and Buttongrass moorland is its stronghold in Australia.

Several mammal and bird species, such as the Common Wombat (*Vombatus ursinus*), Bennett's Wallaby (*Macropus rufogriseus*), Eastern Quoll (*Dasyurus viverrinus*), Short-beaked Echidna (*Tachyglossus aculeatus*), Wedge-tailed Eagle (*Aquila audax*), Black Currawong (*Strepera fuliginosa*) and New Holland Honeyeater (*Phylidomyris novaehollandiae*), use Buttongrass moorland habitat for feeding and typically shelter in other habitats.

Invertebrate fauna

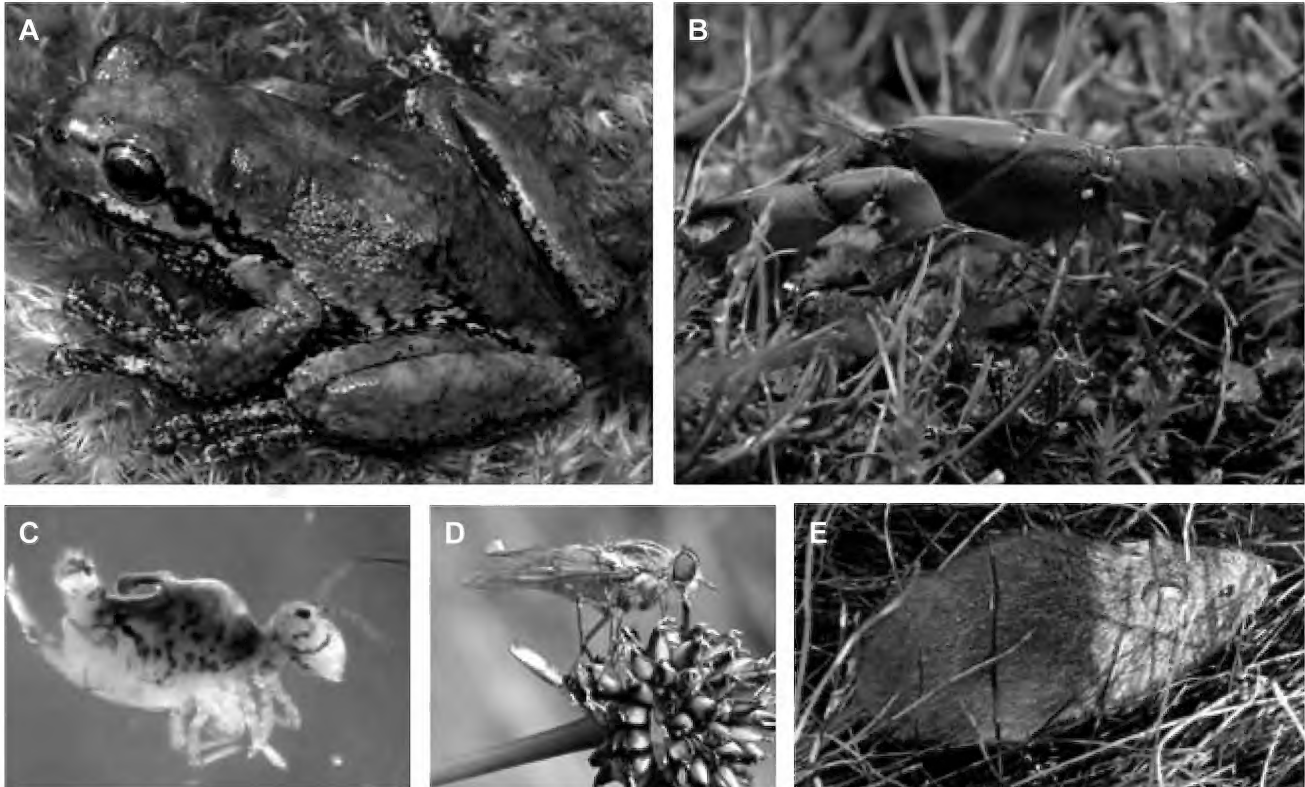
Buttongrass moorland invertebrates have not been well surveyed, particularly the terrestrial fauna, however this situation is improving. Recent surveys using pitfall traps

and sweep nets have found that the terrestrial invertebrate fauna of Buttongrass moorland is numerically dominated by springtails (Order Collembola, Families: Katiannidae, Isotomidae, Bourletiellidae, Katianninae), flies (Diptera: Chironomidae, Muscidae, Ceratopogonidae, Sciaridae), spiders (Araneae: Tetragnathidae, Araneidae, Thomisidae), mites (Acarina: Parakalummidae, Uropodidae), crickets (Orthoptera: Gryllidae) and ants (family Formicidae, subfamily Dolichoderinae) (Greenslade and Smith 1999; Driessen 2006). The most diverse groups recorded, in terms of number of families and morphospecies, are flies, wasps (Hymenoptera), spiders, mites, beetles (Coleoptera), moths (Lepidoptera), bugs (Hemiptera) and springtails.

Unlike many other habitats the diversity and abundance of beetles and ants is relatively low. Presumably the limited number and diversity of trees and shrubs and a poorly

Table 1. Vertebrate fauna known to be able to spend their entire life-cycle within Buttongrass moorlands. Figures in brackets are the percentage of the total number of Tasmanian species for that group. e = Endemic to Tasmania

Mammals (12)	
Swamp Antechinus	<i>Antechinus minimus</i>
Broad-toothed Mouse	<i>Mastacomys fuscus</i>
Swamp Rat	<i>Rattus lutreolus</i>
Birds (2)	
Striated Field Wren	<i>Calamanthus fuliginosus</i>
Ground Parrot	<i>Pezoporus wallicus</i>
Southern Emu-wren	<i>Stipiturus malachurus</i>
Reptiles (24)	
She-oak Skink ^e	<i>Cyclodomorphus casuarinae</i>
White-lipped Snake	<i>Drysdalia coronoides</i>
Metallic Skink	<i>Niveoscincus metallicus</i>
Tiger Snake	<i>Notechis scutatus</i>
Southern Grass Skink	<i>Pseudemoia entrecasteauxii</i>
Amphibians (45)	
Common Froglet	<i>Crinia signifera</i>
Tasmanian Froglet ^e	<i>Crinia tasmaniensis</i>
Smooth Froglet	<i>Geocrinia laevis</i>
Tasmanian Tree Frog ^e	<i>Litoria burrowsae</i>
Brown Tree Frog	<i>Litoria ewingii</i>
Freshwater fish (4)	
Swamp Galaxias ^e	<i>Galaxias parvus</i>



A: Tasmanian Tree Frog *Litoria burrowsae*. B: Burrowing crayfish *Ombrastacoides leptomerus*.
 C: Springtail from the genus *Corynephoria*. D: March Fly from the family *Tabanidae*
 E: Broad-toothed Mouse *Mastacomys fuscus*. Photos: Michael Driessen

developed litter layer restricts their diversity. The acidic and poorly drained soils also limit nesting opportunities for ants, as well as other insects with a soil dwelling life-stage, however jack jumper ants (*Myrmecia* sp.) nests, raised above the water level, are a conspicuous feature in some areas of Buttongrass moorland.

Freshwater invertebrates of Buttongrass moorland have probably received greater attention than their terrestrial counterparts with the burrowing crayfish rightly taking centre stage. Burrowing crayfish have been recognised as keystone species and ecosystem engineers in Buttongrass moorland because of their fundamental role in this ecosystem (Richardson and Doran 2007). Crayfish burrows provide habitat for a discrete fauna, the pholeteros, which is numerically dominated by nematodes, oligochaetes, copepods, isopods and amphipods (Brown *et al.* 1993). Two species of syncarid crustaceans, the pygmy mountain shrimps *Allanaspides hickmani* and *A. helonomus*, that have a close association with crayfish burrows, are of particular scientific interest because: they are very primitive among the higher crustaceans, they possess an unusual structure called the 'fenestra dorsalis', they have Gondwanic origins, and their present day distributions may help us understand past hydrological features and processes in the region. Pools in Buttongrass moorland also provide habitat for an endemic dragonfly the Tasmanian Spotwing (*Synthemioptis gomphomacromioides*). This species, which is the only

member of its genus, is of scientific interest as it is the most primitive member of its family and also has Gondwanic origins.

Rare or threatened species

Buttongrass moorland provides habitat (shelter, nesting, and/or food) for several species listed as threatened under the Tasmanian *Threatened Species Protection Act 1995*: the Orange-bellied Parrot, the Wedge-tailed Eagle, the Tasmanian Devil (*Sarcophilus harrisi*), the Swamp Galaxias, Hickman's Pygmy Mountain Shrimp (*Allanaspides hickmani*) and two species of caddis-fly McCubbins Caddis-fly (*Taskiria mccubbini*) and Lake Pedder Caddis-fly (*Taskiropsyche lacustris*). Of these species, Hickman's Pygmy Mountain Shrimp and the caddis-flies are restricted to Buttongrass moorland, and the Orange-bellied Parrot is dependent on this habitat for food during the breeding season. Hickman's Pygmy Mountain Shrimp occurs only in pools in Buttongrass moorland near Lake Pedder and Lake Gordon in southwest Tasmania and it has been estimated that 85-95% of its habitat was lost with the flooding of Buttongrass moorland for hydro-electric power generation. The two threatened caddis-flies were thought to be extinct following the flooding of the original Lake Pedder, but surveys in 1998 and 1999 found both species in Buttongrass moorland adjacent to Lake Pedder. The Swamp Galaxias is restricted to slow-flowing

swampy streams and soft-bottom pools near Lake Pedder. Like Hickman's Pygmy Mountain Shrimp, the two caddisflies and the Swamp Galaxias have naturally restricted distributions and have lost significant areas of habitat through inundation. The wild population of Orange-bellied Parrots comprises only 200 mature birds. The primary threats to the species occur on the Australian mainland and include loss of critical winter habitat and food supply, and competition with and predation by introduced animals.

Endemism

It would appear that there are relatively few fauna species that are entirely restricted to Buttongrass moorland. No vertebrate species are entirely restricted to Buttongrass moorland, although few of Tasmania's vertebrate species are restricted to any one particular habitat, reflecting the State's small size, glacial history and relatively recent isolation from the Australian mainland. Similarly, few invertebrates are currently known to be restricted to Buttongrass moorland, however, this may be due to taxonomic identification issues and limited systematic invertebrate surveys. But it is also possible that this is because the origins of this habitat are relatively recent or its extent was very restricted in the past.

Threats

Buttongrass moorland is well protected in Tasmania with 66% in secure conservation reserves and much of its distribution within the Tasmanian Wilderness World Heritage Area. As a consequence there are only a limited number of management issues relating to Buttongrass moorland, but these include fire, climate change, disease (such as chytrid fungus and *Phytophthora*) and introduced animals (Driessen 2006).

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The role of burrowing crayfish in Tasmanian sedgeland

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Freshwater crayfish

Australia is home to the second largest radiation of freshwater crayfish (after the southeast of North America), with 11 genera and perhaps 130 species in the southeast and Tasmania, the southwest of Western Australia, and in the coastal strip northwards through New South Wales, Queensland and the Northern Territory. The Tasmanian fauna is comprised of five native genera and at least 33 species, all but two of which are endemic. All of these

animals are burrowers to a greater or lesser extent, but of particular interest for this paper are those species that burrow in the peaty soils of sedgeland. They are found in three genera, principally in the Tasmanian endemics *Omrastacoides* and *Spinastacoides*, but to a lesser extent in *Engaeus*. The first two genera are confined to the western half of Tasmania, while *Engaeus* is also found in the north (Fig. 1).

Crayfish in sedgeland

Because of their low ionic concentrations and high acidity, the soils and waters of Tasmanian sedgeland seem an unlikely habitat for crayfish, which have an exoskeleton strengthened by calcium carbonate. Indeed, there are few other examples of diverse crayfish faunas in peatlands elsewhere in the world, but the relatively mild conditions in Tasmania, without ground-freezing frosts, mean that they are not directly comparable with the extensive boreal peatlands of the northern hemisphere.

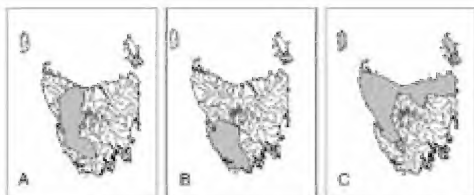


Figure 1. Distribution (hatching) in Tasmania of the genera *Omrastacoides* (A), *Spinastacoides* (B) and *Engaeus* (C).



Figure 2. *Ombrastacoides huonensis*, a sedgeland crayfish from southwest Tasmania. Photo: R.B. Mawbey

Whatever the explanation, Tasmanian sedgeland areas are extensively colonised by crayfish, and 15 or more species can be found there. It is not uncommon to find more than one species at a location and in these places the species partition the habitat on the basis of soil drainage (Richardson and Swain 1980). Sedgeland burrowers have adapted the calcification of the exoskeleton to cope with the very low availability of calcium in their environment. Compared to open water species, *Ombrastacoides huonensis* (Fig.2) concentrates calcium in the parts of the skeleton that experience heavy wear: the tips of the claws, the front of the carapace and the end of the tail (Mills and Lake 1976).

Burrows

Crayfish in the genera *Ombrastacoides* and *Spinastacoides* are often very abundant in lowland sedgeland areas. Their densities may exceed one adult animal per square metre, but the only evidence of their presence is usually the openings of the burrows. A typical sedgeland crayfish burrow may have five or more surface openings, which lead downwards, converging on a single, loosely spiral tunnel ending in a terminal chamber (Fig. 3).

The depth of the burrow depends on the soil profile and the dynamics of the water table, since these species need a supply of ground water for all but a few weeks of the year. Usually the burrow descends through the entire soil profile, terminating just above, or in, the glacial boulder clay or broken bedrock that underlies the peat. On valley floors this may mean a burrow depth approaching two metres, but more commonly the profile is less than a metre deep. On hill slopes the soil may be very shallow indeed (<20 cm), but if the rainfall is sufficient to maintain a water supply, crayfish will still burrow in these slopes.

Each burrow is occupied by a single adult crayfish, apart for a week or two during the breeding season, but females are often found with their brood, usually in the terminal chamber. The crayfish use the burrow for various purposes: it provides shelter from desiccation and predators, a food supply and a protected site for mating and rearing the young. In *Ombrastacoides huonensis*, the most studied

sedgeland species (Growth and Richardson 1988), the diet of adults is almost entirely plant material from two sources: the roots of Buttongrass and other species, and decaying Buttongrass leaves that the animals apparently gather on the surface and drag underground, where they are conditioned by micro-organisms before they are eaten.

Burrows often include upwardly-directed, blind chambers under Buttongrass clumps, where roots are grazed, and there is a positive relationship between burrow volume and the size of the crayfish in the burrow. Since the number and distribution of burrows changes very little over many years, it seems likely that the burrows long outlast their inhabitants, suggesting that the animals compete for the best (largest) burrows, which have the greatest surface area of roots. Large burrow systems often partially collapse near the surface, forming pools that provide habitat for a variety of aquatic animals (Fig. 4).

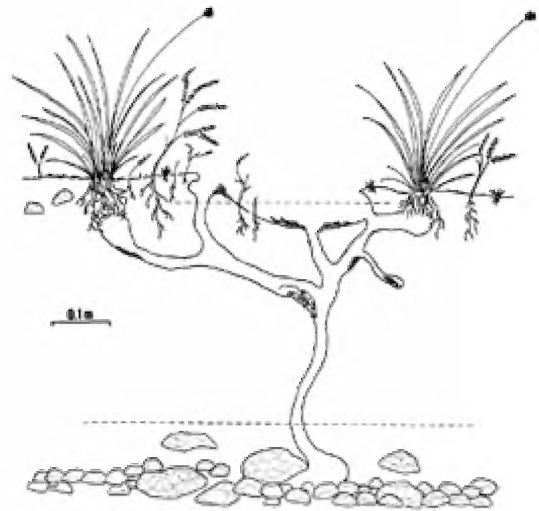


Figure 3. Diagram of a typical sedgeland crayfish burrow, showing collapsed entrances, feeding chambers and a terminal chamber in subsoil. The dashed lines represent the average annual upper and lower levels of the water table. Drawing: Premek Hamr

Ecosystem engineering

At densely-burrowed sites the below-ground surface area of the burrow walls greatly exceeds that of a unit area of the soil surface. Since the peats are consolidated and water-logged, burrows provide a conduit for water and gases into the soil, connecting the surface with the more-pervious sub-soil. When the burrows are flooded the movement of the occupant mixes the water, and when the water table is low air can penetrate deep into the soil. This is reflected in a strong growth of rootlets on the walls of the burrow tunnels and a significantly higher soil respiration rate around the burrows than deep in the soil (Richardson 1983). Some evidence suggests that the burrows affect the growth of surrounding plants (Richardson and Wong 1995), but it is not yet clear whether this effect is generally positive or negative.



Figure 4. Sedgeland near Mt Anne, southwest Tasmania, showing pools formed by surface collapse of a large burrow system of *Ombrastacoides huonensis*.

Photo: Alastair Richardson

Crayfish in Tasmanian sedgelands clearly satisfy the criteria for ecological engineers. As well as the influence of their burrows on soil processes, and perhaps on plant

growth, the burrows and associated pools also provide habitat for a suite of invertebrates, including some rare and endemic species such as dragonflies (*Synthemioptis gomphomacromioides*) and pygmy mountain shrimps (*Allanaspides* spp).

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The diversity of soil mites in Tasmanian Buttongrass moorland in relation to vegetation age

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Introduction

This study focuses on a little known and understood group of invertebrates, the mites (Acarina) that reside in the litter, peat and soils of Buttongrass moorland in Tasmania. Buttongrass moorland, being a highly pyrogenic vegetation type, has a long history of regular burning by Aborigines and currently it is thought that Buttongrass requires a fire frequency of 5-20 years in order to maintain its integrity. Studies in other vegetation communities have indicated that soil invertebrates (including Acarina) are adversely affected by vegetation fires and that it may take many years to recover from a severe fire (Coy 1996). Soil mites are an integral part of the soil fauna and can be responsible for the breakdown of dead organic material, the movement of fungal spores through the soil and for regulating the size of populations of other soil dwelling fauna. An understanding of how soil and litter mite populations are affected by fire will give insights into fire management for conservation and diversity management of invertebrates.

Figure 1. Scanning electron micrograph of a soil mite - *Phthiracarus* sp. 3



The invertebrate fauna of the Buttongrass community is very poorly known (Mallick and Driessen 2005). The present state of knowledge regarding the soil/litter Acarina that reside in the peat accumulations in Buttongrass is non-existent and their overall response to fire is not understood. This paper will address the question, how do the Buttongrass soil mite communities change with time since the last fire?

Methods

A comprehensive survey was undertaken of mites in differing age classes of Buttongrass within the Tasmanian Wilderness World Heritage Area (TWWHA).

Study areas

Two large areas of Buttongrass were utilised, one around Lake St. Clair (42° 10'S 146° 8'E) and another around Lake Pedder (42° 51'S 146° 12'E). Sites were selected within these regions to reflect varying age since the last recorded fire, and were selected from a series of sites identified and recorded by the Tasmanian Parks and Wildlife Service. These sites have been used for a variety of flora and faunal studies, many of which are included in this issue. Table 1 outlines the basic climatic, altitudinal and environmental variation between the two areas.

Table 1. Characteristics of the two study areas

Attribute	Lake Pedder	Lake St. Clair
Altitude range (m)	305-365	730-800
Mean annual rainfall (mm)	2541	1520
Mean summer max temp (°C)	18.3	17.7
pH	3.76 (+/-0.02)	4.05 (+/-0.05)
Organic matter (LOI) (%)	50.53 (+/-6.14)	61.94 (+/-5.65)

Sampling

Six peat-cores were removed from four sites of each age class in both areas at 3-monthly intervals. This equated to 864 cores over the year. Sampling took place at 3-monthly intervals in order to detect as many species as possible; mite diversity has been shown to be seasonal in temperate environments (Block 1966). The localised fire history is different within each of the two regions, and so these areas have had to be treated slightly differently (Table 2). The Lake Pedder region has a longer documented fire history than the Lake St. Clair region which has a more complete series of young (under 10 years) burns.

Table 2. Fire age classes at Lake Pedder and Lake St. Clair

	Age Classes (years since last fire)				
	<10	10-20	20-30	30-40	>40
Lake Pedder					
Lake St. Clair					

The mites were extracted from the soil cores using a Tullgren funnel apparatus, which slowly heats and dries the cores, driving the mites from the soil and into a little collecting jar under the funnel. Extraction was for 7 days and sample surface temperature was approximately 25°C. All mites were identified to species where possible, or to genus or family if taxonomic resolution was unclear.

Results

A total of 13,409 mites were extracted (10,769 + 2640 juveniles) from the cores. These individuals constituted 117 species from 72 families. Of these, five species were very abundant and collectively accounted for 36% of all mites. These five consisted of one species of *Austrocarabodes*, one species of *Nanorchestes*, one species of *Eustigmaeus* and two species of Oppiidae in the genera *Brachioppiella* and *Lanceoppia*. Forty-nine species contributed less than ten individuals and ten species were only represented by singletons.

Figure 2 shows an ordination of the sites based on their mite species. An ordination shows how similar sites are to each other in their composition of mites. So two sites close together on the ordination share similar mites in similar numbers and two sites far from each other on the ordination have few species in common. This ordination indicates that there are differences in the community structure between the Lake Pedder and Lake St. Clair areas; this is evident in the vertical separation of the sites along the y axis. Lake St. Clair (LS) occupies the upper part of the figure and Lake Pedder (LP) the lower half. The x axis separates an age gradation across the graph with the older sites having lower scores on the x axis. Vegetation density is positively correlated with age since fire, as one would expect, and soil nutrient concentrations are higher at Lake St. Clair than at Lake Pedder (results not reported here).

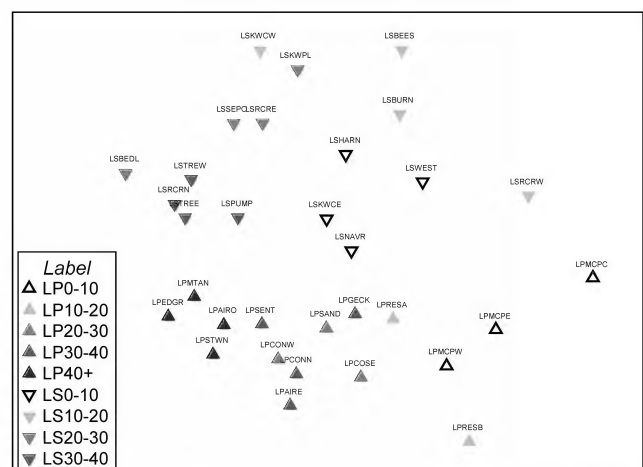


Figure 2. Ordination of mite community grouped by vegetation age class.

The patterns identified by the ordination can to some extent be explained by looking at the population density and species richness at each age class. At Lake St. Clair there are no differences in population densities at the three youngest sites, and then we see a large increase in the 30+ age classes. Similarly, in the Lake Pedder region the pattern is repeated with very large increases in the 40+ years. It is only these two age classes that are statistically different from the rest.

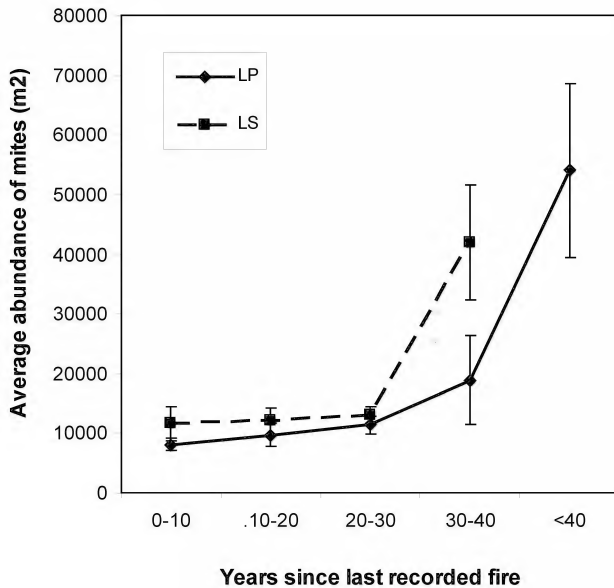


Figure 3. Mean population density of mites at the different vegetation age classes

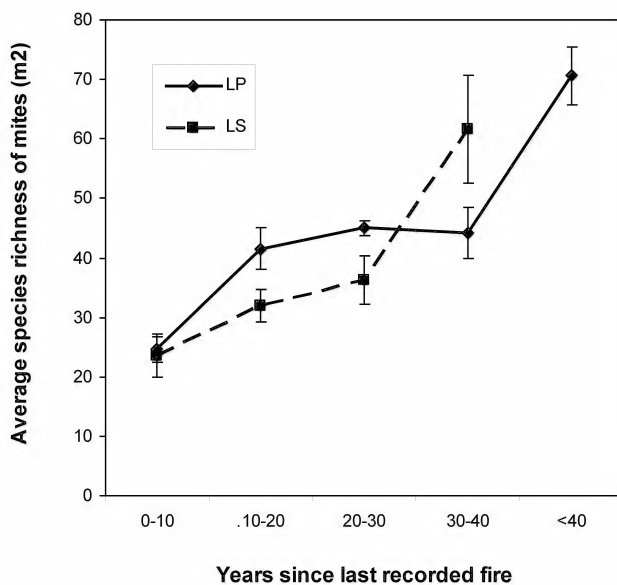


Figure 4. Mean mite species richness at the different vegetation age classes

Species richness exhibits a very similar pattern. There is again a significant difference between the younger and older age class sites, with both Lake St. Clair 30+ age classes and Lake Pedder 40+ years exhibiting a large increase in species numbers.

Conclusions and recommendations

So what does this mean? Firstly Buttongrass soil mite communities remain fairly static and similar in their composition for up to 30 years after fire. After this time, communities experience huge growth not only in mite density but also in the numbers of species present. The species compositions are also subtly different between the two regions. For one or several reasons it takes many years to establish diversity amongst mites in Buttongrass soils.

The role that vegetation diversity and litter production play in driving the diversity in mite communities in this environment is still untested, but it is likely that the quantity and quality of plant leaf litter will play a large part in shaping the resident mite community.

This idea that certain taxa may act as a sort of memory of major disturbance in soils, is played out well with mites in Buttongrass moorland (Ruf 2000). Their relatively low abundance and density remains as a disturbance signal in these soils, for they require many years to recover from fire. For this reason it would be advisable to burn Buttongrass to form mosaics of varying aged stands, with emphasis on preserving as much as possible in the 30 years or older state.

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The distinctive limnological character of southwest Tasmania

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Southwest Tasmania has always had the stamp of its own character. Even the most lay traveller knows that the west coast starts in the middle of the island. A line slanting north west by southeast through Derwent Bridge defines a natural frontier of profound and abrupt climatic, geologic, vegetational and edaphic change separating the grazing lands of the east from the dank forests and sodden plains of the west. Many species of plants and animals occur on one or other side of the line but not both. Others such as possums and some butterflies, with wider distribution, may change in appearance as the line is crossed. The hallmark of the west coast is jagged quartzitic topography, Buttongrass plains and rainforest (Fig.1).

Scattered across the western Central Plateau and in the embrace of montane corries are about 3,000 lakes and tarns that have been minimally influenced by human activity. They lie in catchments still with a raiment of natural vegetation, remote from agriculture and as natural as can be. A survey of the limnological attributes of 300 of them reveals that they occupy two distinct and distinctive limnological provinces that are related to the chemistry and geology of the underlying soils (Tyler 1992).

Two limnological provinces

The water source for the lakes and rivers is the rain swept across the island by the prevailing roaring forties. Its chemical composition, as measured by the atomic frequencies of the eight major ions, is closely akin to that of seawater. In the eastern province, on its way to lakes and rivers, the rainfall percolates through soils derived from



Figure 1. The face of the western province. Photo: Peter Tyler

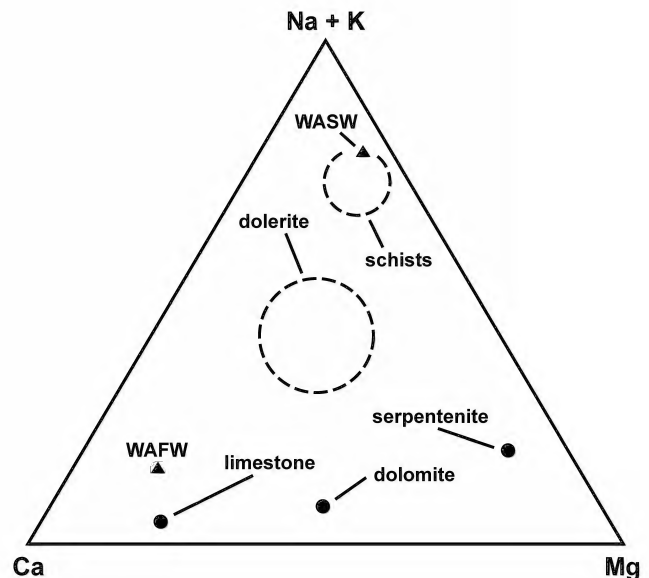


Figure 2. Three-way plot of cationic proportions showing clustering of eastern (dolerite) and western quartzitic (schists) lakes, and the chemical signatures of creeks on other rock outcrops. WAFW=World Average Freshwater. WASW=World Average Seawater.

predominantly Jurassic rocks that are relatively yielding of divalent cations and anions. The resultant lake waters are enriched with calcium and magnesium bicarbonates, their pH is consequently circum-neutral and their ionic complexion has shifted from that of seawater to cluster closer to the international datum of 'World Average Freshwater' (Fig. 2).

The west coast waters stand out clearly from this. A mantle of peat denies the percolating rainwater access to underlying Precambrian and Ordovician rocks which, in any case, have little to offer in the way of weatherable minerals. The acid waters retain the ionic fingerprint of their westerly ocean, so starved of calcium that local crustaceans reserve it for the most essential parts of their skeleton. Only where soft rocks, like Mt. Anne's dolomite flanks or the Sawback Serpentinities, thrust up through the peats, like chemical nunataks, do the waters pick up divalent ions and approach or surpass the composition of average freshwater (Fig. 2).

Waters of the two provinces are also clearly distinguished by their optical properties. Lakes of the eastern province contain crystal-clear waters in which the attenuation pattern of light penetrating the waterbody closely resembles that

for pure water. The green wavelengths penetrate furthest and to great depth in these 'Deep Green Window' lakes (Fig. 3). In the western province the waters are brewed to the colour of tea in the peats of Buttongrass and forest. The rivers run brown and acid to sombre, topaz lakes and lie black in the pools of the plains. In these 'Dim Red Window' lakes, deeply stained by soluble humic substances (i.e. dystrophic), all wavelengths except red are abruptly attenuated in the first metre and the red itself reaches little further. The heavy colouring also influences the thermal properties of western lakes in ways not evident in the clear eastern waters.

Two plant and animal communities

Just as terrestrial plant and animal communities on opposite sides of the ecological divide differ, so too the physical and chemical dichotomy between western and eastern lakes is matched by biotic differences. Among aquatic animals, the copepods, for example, have species that are resolutely western and others that are fastidiously eastern. Chemical differences may be at work in these cases. For the photosynthetic algae the optical differences must have strong influence. The green world of the eastern lakes would best suit green algae whose pigment arrays ideally harvest the prevailing wavelengths. The dim red world of western lakes would favour algae from the golden-brown algae with pigments chromatically complimentary to the long red wavelengths. This notion has not been satisfactorily tested but early indications are that it will hold.

The colour of western waters

The genesis of the humic substances colouring the western waters is not fully known. A glance at a pool in a Buttongrass plain leaves no doubt that vegetable exudates originating there are major contributors but it is also valid to expect an input from the soils of temperate rainforests. Comparing the occurrence of brown waters with the terrestrial ecological scene points to pedological processes in Buttongrass and rainforest soils overlying Precambrian and Ordovician strata. The line of change is approximately aligned with the 'Jurassic Edge'. Lakes of the eastern province, lying on Jurassic dolerite clothed with east coast vegetation are devoid of the brown colouration. The dividing line between eastern and western domains has sometimes been called the 'Tyler Line' (Vyverman *et al.* 1996) but Tyler (1992) himself prefers the term corridor. In this zone the change from deep green window to dim red window, too subtle to be detected by eye, can be revealed by the spectrophotometer (Fig. 3).

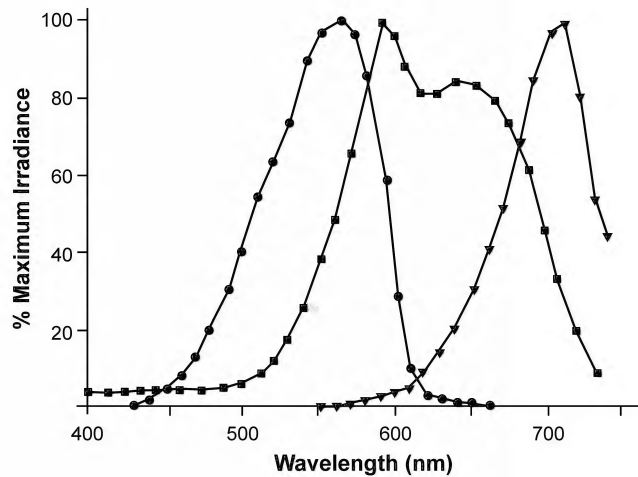


Figure 3. The irradiance at different wavelengths for a typical eastern 'Deep Green Window' lake (Lake Perry), a typical western 'Dim Red Window' lake (Lake Chisholm) and for Lake Judd in the limnological corridor of change between east and west.

Lake Judd lies in a glacial trough surrounded by steep walls clothed in rainforest. Its catchment is virtually limited to these walls. Geographically and by virtue of its vegetation it lies deeply within the western province but it is a dolerite massif virtually surrounded by the Precambrian. To the eye its waters appear clear but its spectral bandpass (Fig. 3) reveals considerable attenuation and a slewing of the light climate towards the red end of the spectrum. It seems that while west coast vegetation on west coast rocks inevitably spells highly humic waters, west coast vegetation on east coast rocks can also go part of the way along the same path. The distribution of diatoms confirms a corridor of change rather than a strict geological line of demarcation between eastern and western provinces (Vyverman *et al.* 1996).

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Death on the moor: the impact of *Phytophthora cinnamomi* on Buttongrass moorland

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Background

The introduced plant pathogen *Phytophthora cinnamomi* (PC) is well known for causing disease epidemics in heathland and dry sclerophyll plant communities across the higher rainfall zones of southern Australia [see APC 13(4)]. PC is also widespread in Buttongrass moorlands in Tasmania (Fig. 1). PC is listed as a key threatening process under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and its impacts on both the structure and floristics of Buttongrass moorland vegetation far exceed that of fire.

Buttongrass moorland soils are generally nutrient poor, acidic and near saturation point for most of the year providing ideal conditions for PC to thrive. The open nature of moorland vegetation results in warm summer soil temperatures that are conducive to the growth of the pathogen.

Susceptible plants may be killed by PC infecting roots and spreading to the base of the stem. The symptoms of infection are similar to drought, with leaves turning brown, red or black. The pathogen releases spores into the soil. PC may spread into uninfested areas by the movement of infected soil, water or plant material. Both wildlife and humans are a major vector for the spread of infected soil across both short and long distances.

Extent of disease in Buttongrass moorland

PC is widespread throughout the geographic range of Buttongrass moorland in Tasmania. Although the extent is hard to judge as mapping disease mosaics is problematic, there are likely to be tens of thousands of hectares of infested moorland. PC has an altitudinal limit of around 700 m in the west grading up to about 800 m in the northeast. Consequently, there is a refugium from disease in high altitude Buttongrass moorland communities. However, there are no altitudinal refugia within the Flinders and South East bioregions, and nor for the "Western lowland sedgeland" community.

Most of the large areas of Buttongrass moorland in eastern Tasmania are extensively diseased (e.g. Tasman and Freycinet National Parks). Although there are large areas of Buttongrass moorland in the west of the State infested by PC, the vast majority of Buttongrass moorlands there are free of the pathogen. Most infested areas are associated with historic mining activity, hydro-electric development, roads or walking tracks. Occasional spot infestations do occur away from substantial human disturbance. The flow of water across the landscape is clearly a major mode of

local spread of PC and it is also apparent that wildlife is another natural vector for spread. The incremental spread of PC has been observed along walking tracks. New infections have also been observed following new track and road construction.

Susceptibility to disease

Currently 48 moorland plant species are known to host PC (Table 1), including one species, *Epacris curtisiae*, listed as rare (*Threatened Species Protection Act 1995*). A number of hosts are resistant or only moderately affected by PC and these species may assist in maintaining disease activity within the vegetation over time. Although not known hosts, the parasitic plants *Exocarpos syrticola* and *Euphrasia gibbsiae* have had severe population declines in diseased areas.

Where Buttongrass moorland vegetation occurs on better drained or lower fertility sites, generally there is a greater abundance of susceptible species (Table 2).

Disease impact

A controlled longitudinal study was established in 1988 at Red Knoll and Bathurst Harbour in the South West National Park to investigate the impact of PC on Buttongrass moorlands. Community floristics, vegetation structure and biomass have all been significantly affected. The initial infestation by PC resulted in 100% mortality in populations



Figure 1. Disease caused by *Phytophthora cinnamomi* in recently burnt Buttongrass moorland, southwest Tasmania.
Photo: Tim Rudman

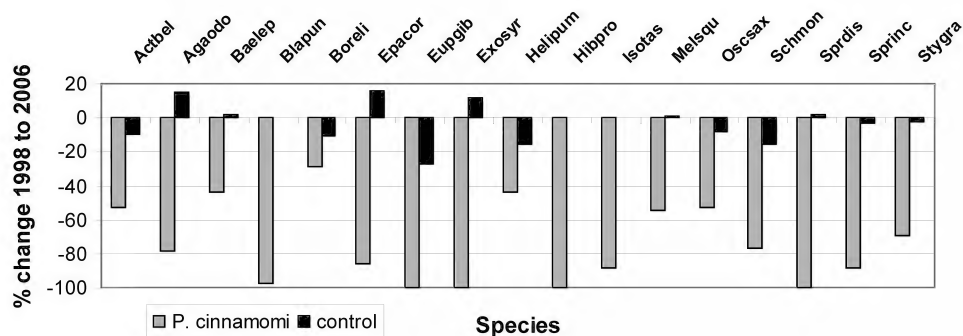


Figure 2. Percentage change in frequency for selected species following infestation by *Phytophthora cinnamomi*. (Scientific names abbreviated to the first three letters of the genus name followed by the first three letters of the species epithet, see Table 1 or text for full names).

of *Sprengelia distichophylla*, *Hibbertia procumbens*, *Euphrasia gibbsiae* and *Exocarpos syrticola*. Greater than 80% mortality and ongoing disease is present in populations of *Blandfordia punicea*, *Isophysis tasmanica*, *Sprengelia incarnata*, *Epacris corymbiflora* and *Agastachys odorata* (Fig. 2). No significant change in populations of these species occurred in non-infested plots.

The longer term outcome of the presence of disease on the community is a complex interaction between PC, plants and the environment. A study at Forest Lagoon (Brown *et al.* 2002) showed that over 20 years there was an unambiguous impact from PC on the moorland community. Structural complexity, biomass and floristic composition were all altered. The effect of disease on moorland floristics was opposite to that of time since fire. This demonstrates that PC is a significant new ecological process within Buttongrass moorland vegetation.

Other unpublished data on the impact of PC at Forest Lagoon demonstrates a post-infestation collapse in populations of *Sprengelia incarnata*, *Agastachys odorata*, *Baeckea leptocaulis* and *Epacris corymbiflora*. Recent monitoring work at the same site has shown relatively little change in populations in the following 20 years irrespective of a wildfire regeneration event. Moderately susceptible species may respond in novel ways. For instance, *Bauera rubioides* declined in population with the initial disease epidemic, but surviving plants increased their cover to greater than pre-infestation levels, probably as a result of reduced competition from other species.

How highly susceptible plants will respond in the longer term is less certain. Those species that are eliminated from diseased areas in the short to medium term are unlikely to re-establish. Species that persist in small populations are also vulnerable to elimination from stochastic events. The most vulnerable species are those that are both highly susceptible to the pathogen and have reproductive strategies that include long juvenile periods, predominantly vegetative reproduction or aerial seed banks. The interaction of fire and PC will be an important area for future research to determine the risks and opportunities of using fire for the management of highly susceptible species.

The prognosis for the long term survival in infested moorland areas of the dominant emergent shrubs *Banksia*

marginata and *Agastachys odorata* and the endemic species *Blandfordia punicea*, *Sprengelia distichophylla* and *Isophysis tasmanica* is poor. The parasitic plants *Euphrasia gibbsiae* and *Exocarpos syrticola* may also be at risk. Other highly susceptible species such as *Sprengelia incarnata* persist because they are able to mature rapidly but they are greatly reduced in abundance and size.

Behaviour of inoculum

Soil-borne inoculum remains at high levels in infested areas for at least 25 years. This affects the success of re-establishment of susceptible species over time. High levels of inoculum are also present in the surface soil throughout the cold winter months when soil temperatures are too low to support the release of reproductive spores. Thus, the pathogen has potential to disperse year round.

Management

Management is currently restricted to preventing people from spreading PC into disease-free areas. Management actions include track closures, access controls, hygiene prescriptions, washdown stations on walking tracks and movement controls on soil and plant material. Greatest priority for management is given to a suite of *Phytophthora* management areas. These are either large disease-free areas or sites that are practical to manage, selected from within each bioregion and containing representative examples of plant species and communities most at risk from PC (Schahinger *et al.* 2003).

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Table 1. Susceptibility of Buttongrass moorland plants to *Phytophthora cinnamomi*. Susceptibility established from field observation (F) or glasshouse experiment (G). Updated from Podger et al. (1990).

Family	Species	Susceptibility
APIACEAE	<i>Actinotus bellidioides</i>	low-moderate susceptible G
	<i>Allocasuarina monilifera</i>	host
CASUARINACEAE	<i>Allocasuarina zephyrea</i>	low - moderately susceptible F?
	<i>Bauera rubioides</i>	low - moderately susceptible F?
CUNONIACEAE	<i>Hibbertia procumbens</i>	moderately susceptible GF
DILLENIACEAE	<i>Epacris corymbiflora</i>	highly susceptible F
EPACRIDACEAE	<i>Epacris curtisiae</i>	highly susceptible GF
	<i>Epacris gunnii</i>	highly susceptible G
	<i>Epacris impressa</i>	low - moderately susceptible
	<i>Epacris lanuginosa</i>	low - moderately susceptible GF
	<i>Epacris obtusifolia</i>	moderately - high susceptible
	<i>Leptecophylla juniperina</i>	moderately - high susceptible F
	<i>Leucopogon collinus</i>	highly susceptible GF
	<i>Monotoca submutica</i> var. <i>submutica</i>	highly susceptible F ?
	<i>Sprengelia distichophylla</i>	highly susceptible F
	<i>Sprengelia incarnata</i>	highly susceptible FG
EUPHORBIACEAE	<i>Aotus ericoides</i>	highly susceptible F
	<i>Dillwynia glaberrima</i>	highly susceptible F
FABACEAE	<i>Oxylobium ellipticum</i>	highly susceptible
	<i>Schizacme montana</i>	host
LOGANIACEAE	<i>Mitrasacme pilosa</i>	moderately susceptible host ?
	<i>Baeckea leptocaulis</i>	moderately - highly susceptible GF
MYRTACEAE	<i>Eucalyptus nitida</i>	resistant host
	<i>Leptospermum scoparium</i>	resistant host
	<i>Melaleuca gibbosa</i>	resistant host
	<i>Melaleuca squamea</i>	moderately susceptible GF
	<i>Melaleuca squarrosa</i>	resistant host
	<i>Agastachys odorata</i>	highly susceptible GF
PROTEACEAE	<i>Banksia marginata</i>	highly susceptible GF
	<i>Persoonia gunnii</i> var. <i>gunnii</i>	host
	<i>Persoonia muelleri</i>	highly susceptible G
	<i>Boronia citriodora</i>	highly susceptible
RUTACEAE	<i>Boronia elisabethiae</i>	moderately - highly susceptible GF
	<i>Boronia parviflora</i>	low? susceptible GF
	<i>Boronia pilosa</i>	moderately - highly susceptible GF?
STYLIDIACEAE	<i>Stylidium graminifolium</i>	moderately susceptible GF
CYPERACEAE	<i>Gahnia grandis</i>	resistant host
	<i>Gymnoschoenus sphaerocephalus</i>	resistant host
IRIDACEAE	<i>Isophysis tasmanica</i>	highly susceptible F
	<i>Patersonia fragilis</i>	resistant host
LILIACEAE	<i>Blandfordia punicea</i>	highly susceptible F

Table 2. Susceptibility of Buttongrass (Bg) moorland mapping units (Harris and Kitchener 2005) to *Phytophthora cinnamomi*.

Highly susceptible	Mod-low susceptible
Bg moorland with emergent shrubs	Eastern Bg moorland
Sparse Bg moorland on slopes	Western lowland sedgeland
Western Bg moorland	Restionaceae rushland
Bg moorland undifferentiated	Pure Bg moorland

Impacts and management of recreational walking on Buttongrass moorland

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Introduction

Buttongrass moorlands swathe many valleys and slopes in western Tasmania and as such are generally traversed by bushwalkers en route to a range of destinations; more than 300 kilometres of walking tracks in Tasmania traverse Buttongrass communities. Repeated trampling ultimately results in the development of an impacted corridor, which with ongoing use becomes a wide, braided and boggy 'track'. The rate at which such impacts develop, and the scale of impact produced by a given number of walker passes, varies with vegetation, soil and environmental factors (Whinam and Chilcott 2003).

Recreational impacts

In Buttongrass moorlands, drainage and slope are the primary environmental factors influencing development of recreational impacts, with the structural nature of local vegetation (degree of scrubbiness and relative ease of diverging from the trampled corridor) also important. Trampling affects both the local environment (alteration of drainage, soil erosion, vegetation loss and change)

and visitor experiences (user comfort, aesthetic issues). In sloping terrain gullying, water-flow and ongoing erosion can result. Where organic soils are deep, serious entrenchment can occur. On the flat, poorly-drained plains braided and boggy tracks are typical.

A curvilinear relationship between impacts and amount of use has been consistently documented by many international studies in a wide range of environments (Hammit and Cole 1998). Impacts can develop rapidly (within a few years) but are maintained and can continue to escalate slowly for decades, even at relatively low use levels.

Long term monitoring on several Tasmanian walking tracks provides quantitative data and some basis for modelling such changes (Dixon *et al.* 2004). For example, figure 1 plots data from monitoring sites in two Buttongrass-dominated areas. Rates of change (track widening) are generally greater earlier in the development and evolution of a track (Cracroft valley, where a new track was established in 1990) when compared with a mature or long-established track (Arthur Plains). Comparing sites in the Cracroft valley with different local environmental settings, greater rates of change are observed in wetter or poorly-drained settings (Type B versus Type 2, see figure 1). Track sections are classified into Types according to their environmental variables, as detailed in Dixon *et al.* (2004).

Management

There are many possible approaches to the management of recreational impacts all of which involve the modification of either use-related or environmental factors (Hammit and Cole 1998, Leung and Marion 2000).

Modification of use-related factors comprises a range of approaches from education to regulation, and includes the most controversial tools (e.g. access restrictions). All usually require long-term managerial and resource commitment to be effective. Education has proven effective at modifying some aspects of bushwalker behaviour in Tasmania (O'Loughlin 1997) and, more recently, regulated seasonal use of the Overland Track has limited some impacts there. However, more widespread and controversial approaches to modifying use, while publicly canvassed, have never been constructively discussed or implemented in Tasmania.

Modification of environmental factors generally takes a more direct or straightforward approach. It often involves discrete projects, better suited to temporal variations in funding availability and land management agency

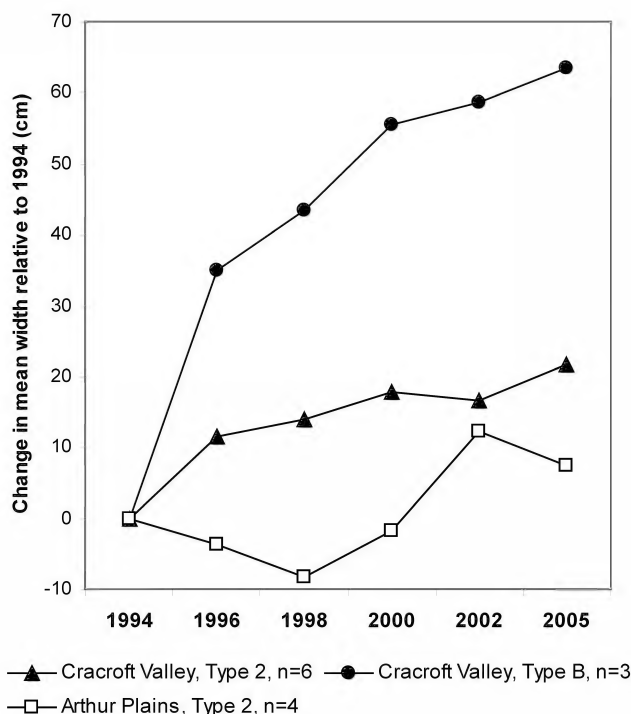


Figure 1: Track width at monitoring sites on the long-established Arthur Plains track (established 1960s) and the more recent Cracroft Valley track (established 1990).

modus operandi, and usually focuses on producing an immediately visible result that is easy to display. The most common approach is to 'harden' the impacted surface, although relocation of the impact (track re-routing) to more robust terrain is also undertaken.

'Hardening' techniques involve covering the impacted or potentially-impacted surface with a robust material, aiming to prevent ongoing impacts and can facilitate peripheral revegetation. Surfacing materials include wood (planking, boardwalks, cording), gravel (including turnpiking) and rock. Planking can be laid relatively rapidly and is useful where impacts are not too advanced. Elevated boardwalks might be constructed where impacts are well-developed and the ground wet. Turnpiking, with side drains, is a robust technique but slow to construct and requires a terrain slope to be effective. Rock surfacing is the most robust and aesthetically-benign technique but, even with an adequate local source of stone, is costly. Costs for any hardening vary, but can be high in remote areas where both materials and track workers must be flown in by helicopter. The long-term maintenance responsibilities of such infrastructure must also be embraced, a significant and growing recurrent responsibility for land managers.



Walking tracks in Buttongrass areas of western Tasmania typically develop into boggy corridors.
Photo: Grant Dixon

Hardening can introduce a considerable amount of infrastructure into a sometimes-remote and otherwise natural area. In such situations the infrastructure itself can then influence the walker experience. This involves more than merely aesthetic issues; hardening also generally renders a section of track easier and more inviting to walk, potentially increasing use and relocating impacts to areas beyond the hardened section.

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Report on the Second Workshop on the Reintroduction (repatriation) of Threatened Plant Species, Volgograd, Russia

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At the request of the ANPC National Committee, I attended the Second Workshop on the Reintroduction (repatriation) of Threatened Plant Species, 16–17 October 2007, in Volgograd, Russia. The workshop was well attended by staff from Botanical Gardens across Russia, including Moscow, Rostov, Siberia, the Urals, St Petersburg and Vladivostok, and was hosted by the recently established Volgograd Botanical Gardens. Also present was Joachim Gratzfeld, Director of Regional Programs, Botanic Gardens Conservation International (BGCI) (UK). The aim of the workshop was to develop an approach to preparation of a manual for plant reintroduction in Russia.

The purpose of my visit was to provide training in a range of methodologies currently being used to reintroduce threatened plant species in temperate and semi-arid landscapes in southern Australia. Because much of the Australian environment faces significant threats to plant conservation at a continental scale, many of the challenges faced by Russian and Australian conservation biologists are similar in scope.

My presentations began with an overview of the southern Australian environment and the threats to survival of threatened flora. I then spoke in detail about

pre-translocation assessment, planning and preparation drawn from the ANPC *Guidelines for the Translocation of Threatened Plants in Australia* (2004). I discussed a range of issues, within a decision making framework, such as consideration of why a translocation should take place, biological and ecological assessment of the species and the translocation site, appropriate propagation methods, collection of source material, determining the number of plants needed to establish a viable population and the short and long term goals of translocation. Preparation and expert review of a translocation proposal and the formation of a translocation team to build capacity were of particular interest to the workshop audience.

Several approaches to translocation were described but case studies focussed on adaptive experimental approaches and how incorporating these into university and community activities can also result in significant gains in knowledge. I provided examples from Victoria and South Australia for species in the Asteraceae (*Brachyscome muelleri*) and Orchidaceae (*Caladenia hastata*, *Diuris fragrantissima*).

I then had the opportunity to hear Russian case studies and to compare these with the Australian experience. There were surprising similarities—many threats, such as illegal plant collection, were shared between the two countries. There were also biological similarities between floras adapted to environmental extremes (e.g. Iridaceae, Orchidaceae) and species in the same genus (e.g. *Stipa*) were subject to reintroduction using similar direct seeding methods.

A number of issues arose during discussions in the workshop forum, many of which are familiar themes in Australian conservation. In particular, prioritisation of species was hotly defended by botanists from regional centres such as the Botanic Gardens of the Urals State University. The Russian flora is categorised according to IUCN criteria and regional Red Lists are prepared in



Lotus re-introduced to a dam near Volgograd.
Photo: Fiona Coates

addition to a national Red List. This system is comparable to Australian state and national lists. Concerns over conservation of local flora versus national priorities were debated.

Another issue was the use of the term ‘translocation’, with ‘reintroduction’ or ‘repatriation’ preferred. This reflected the structure of the Russian system where threatened flora are propagated in botanic gardens, many of which are within universities, with a view to returning species to the wild.

Monitoring was also a prominent issue. At present, the success or failure of translocation is largely unquantified and practitioners were very interested in the experimental approaches which I described. Monitoring is an issue which we have all grappled with over the years. However, monitoring guidelines have been developed recently in Victoria and elsewhere, and development of monitoring and analysis methods specifically for orchids are well advanced.

Participation in the workshop demonstrated that there are a number of areas in which the ANPC could contribute to global conservation by providing training or advice, particularly through links to BGCI. In all, the trip was very successful and I am most grateful for the opportunity. A number of presentations were supplied by Phil Ainsley at very short notice which included work by him and ANPC colleagues, in particular Tricia Hogbin, Bob Makinson, Maria Matthes, Leonie Monks and Maurizio Rossetto. Additional material was supplied by Manfred Jusaitis (Botanic Gardens of Adelaide), Andrew Pritchard (DSE) and Zoe Smith (RBG Melbourne).



Volgograd Botanic Gardens. Photo: Fiona Coates

Report from New Zealand Plant Conservation Network

Bec Stanley

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Network AGM

The AGM was held in October. New Zealand's leading plant conservationists were recognised with awards from the Network in the categories of councils, schools, nurseries and individuals. The awards recognise the depth of feeling for New Zealand's indigenous flora, and the remarkable volunteer efforts of a range of people and organisations.

Plans are being made for the 2008 Conference to be held in Wellington at Te Papa. This will be five years on from the inaugural meeting of the Network in Wellington. This Conference will be a major event in respect of looking to the next five years and also in respect of a celebration of native plants of New Zealand.

Keynote address

Dr Matt McGlone, Science leader at Landcare Research (a Crown Research Institute), gave his keynote address to the annual Network AGM. The title of his talk was: "The NZ Biodiversity crisis: symbolic gestures, imaginary friends and real loss". Dr McGlone focussed on three key issues: Biodiversity loss in NZ (the fact that we have already messed things up over generations and that the public appear to be unaware of the current crisis); the many symbolic gestures that pretend to or apparently address the problem but fail (such as getting out and doing it but not assessing the results, killing pests unless part of an island or mainland island programme, attending international workshops and conferences, and

planning without budgets); and finally our imaginary friends (such as using ecosystem services to promote biodiversity conservation, urban biodiversity initiatives and the focus on climate change related biodiversity losses). He suggested that NZPCN must demonstrate that there is a plant conservation crisis and mobilise the masses.

Website fact sheets and images

Our key way to raise awareness and attempt to mobilize the masses is the Network's website, which continues to grow with over 850 fact sheets now complete and over 85% of the indigenous flora now illustrated. All acutely and chronically threatened plants, all orchids and many other groups of plants are finished. Visitation to the website has grown steadily as the Network has added more and more features to the site. It now receives over 10,000 visits per week and has reached a total of one million visits.

View *Trilepidea*, the E-Newsletter of the New Zealand Plant Conservation Network:

November 2007

<http://www.nzpcn.org.nz/documents/Trilepidea-48-071121.pdf>

An archive of *Trilepidea* is at: http://www.nzpcn.org.nz/newsletter_publications/newsletter_archive.asp

To join the New Zealand Plant Conservation Network, go to: http://www.nzpcn.org.nz/how_to_join/index.asp

Research Roundup

The Victorian Mallee. (2006) *Proceedings and Transactions of the Royal Society of Victoria* 118(2). Special issue of 19 articles, including:

White, M.D. **The Mallee vegetation of north western Victoria**, 229-243.

Parsons, R.F. **Threatened vascular plants of north-west Victoria**, 333-340.

James, E.A. and McDougall, K.L. (2007). **Extent of clonality, genetic diversity and decline in the endangered mallee *Eucalyptus imlayensis***. *Australian Journal of Botany* 55(5): 548-553.

Lunt, I.D., Jansen, A., Binns, D.L. and Kenny, S.A. (2007). **Long-term effects of exclusion of grazing stock on degraded herbaceous plant communities in a riparian *Eucalyptus camaldulensis* forest in south-eastern Australia**. *Austral Ecology* 32(8): 937-949.

McIvor, J.G. (2007). **Pasture management in semi-arid tropical woodlands: dynamics of perennial grasses**. *The Rangeland Journal* 29(1): 87-100.

Morgan, J.W. (2007). **Relationship between fire frequency and nitrogen limitation on foliage production in a native grassland community in Victoria, Australia**. *The Rangeland Journal* 29(1): 101-105.

Pahl, L.I., Weier, L.Z., Sallur, N.M., Bull, A.L. and Howard, B.M. (2007). **Drivers for uptake of environmental management systems by pastoralists in western Queensland**. *The Rangeland Journal* 29(1): 13-23.

Rowarth, J.S., Hampton, J.G. and Hill, M.J. (2007). **New Zealand native seed germination requirements: a review**. *New Zealand Journal of Botany* 45: 485-501.

ANPC Conference and Workshop

ANPC 7th National Conference Our declining flora – tackling the threats

PUT THIS IN YOUR DIARY NOW!

21–24 April 2008

Location: Mulgoa NSW (near Penrith, western Sydney).

The ANPC and Mount Annan Botanic Garden invite you to a conference on threatening processes in plant conservation. Papers and suggestions for workshop topics are also invited.

The conference will focus on four main sub-themes:

- types of threat;
- responding to threats at the species level;
- responding to threats at the plant community level; and
- responding to threats at the landscape level.

For more information, see the back cover of this issue and the ANPC website <http://www.anpc.asn.au/conferences.html>

Contact the ANPC Office for further information on the workshop or conference

Phone: 02-6250 9509 Email: anpc@anpc.asn.au
Web: <http://www.anpc.asn.au>

AFTER THE FENCE – Wheatbelt Woodlands- Management and Restoration

Monday 17 & Tuesday 18 March 2008, Northam WA

Thursday 27 & Friday 28 March 2008, Moora WA

These workshops will build on the knowledge and skills of the community of the Western Australian Wheatbelt in restoring and managing their iconic woodlands.

The workshop will be a mix of presentations by experienced woodland managers, case-studies and hands-on tasks at field sites. Participants will expand their skills and knowledge, exchange ideas and expertise, work with experts and meet other people working to manage Wheatbelt Woodlands.

Themes include:

- the ecological principles essential to planning for management;
- understanding the task (the goal for the site, planning, resources, assessing site and vegetation condition, issues such as soil health, monitoring and ongoing management); and
- applying ecological principles to woodland management (local case studies, site visits, demonstration and trialling of techniques).

These workshops are supported by WWF-Australia, the Northern Agricultural Catchments Council, the Avon Catchment Council and the Australian Government's Envirofund.

Conferences and Workshops

Association of Friends of Botanic Gardens 2008 Conference Where Passion Bears Fruit

4-6 April 2008

Clover Hill Function Centre, Orange Botanic Gardens, NSW

The conference will be conducted over two days and consist of lectures, workshops and walks. Speakers include: Steve Corbett (former Director: RBG Hobart, current Director: Centennial Park & Moore Park Trust), Peter Mortimer (Advertising Account Executive WIN & NBN TV) and Mary Moody (Horticulturist, author and tour guide).

The Conference is hosted by Friends of the Orange Botanic Gardens, NSW. Secretariat: Jane Arnott, phone 02 6362 0039. Conference booking form (click on Events in the menu to the left of screen and scroll to the bottom of the page): <http://www.friendsbotanicgardens.org/>

16th Australian Weeds Conference Weed Management 2008 - hot topics in the tropics

18-22 May 2008

Cairns Convention Centre, Qld

This Conference is hosted by The Weed Society of Queensland Inc. The conference will showcase recent advances in weed science, extension and policy across Australian and international communities and landscapes. The program for the conference includes plenary, oral, and poster sessions and trade exhibitors. The conference will appeal to anyone involved in weed R&D, management and extension and will be a great opportunity to build new networks and explore existing ones.

Further information: <http://www.16awc.com.au/>

ANPC Corporate Members

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Our declining flora

TACKLING THE THREATS



Australian Network for Plant Conservation Inc (ANPC)

7th National Conference

April 21–24 April 2008, Mulgoa NSW (near Penrith, western Sydney)

SECOND ANNOUNCEMENT: CALL FOR ABSTRACTS AND REGISTRATION

The Australian Network for Plant Conservation and Mount Annan Botanic Garden would like to draw your attention to this conference, and ask you to:

- distribute this notice to members of your organisation (as relevant), or to networks with an interest in plant conservation,
- consider submitting abstracts for oral and/or poster presentations (on- or off-theme) for this conference (deadline for abstracts: 15 February 2008; late abstracts will be considered up to 29 February)
- register for the conference and book accommodation

The conference will bring together plant conservation practitioners from around Australia and New Zealand, and will focus on threatening processes and the responses we can effectively make.

The registration, accommodation and abstract form and important information are found at:

<http://www.anpc.asn.au/conferences>

Early registration is appreciated and will ensure onsite accommodation. There is a lively social program including a welcome function, BBQ and conference dinner offsite. The proposed field trips will cover a variety of plant conservation topics using Western Sydney examples.

As this is an opportunity for the plant conservation community to meet in a national forum, we will also consider expressions of interest for workshops, meetings or other appropriate contributions to be conducted during the conference - use the abstract submission form or contact the organisers directly (cathy.offord@rbgsyd.nsw.gov.au or 02 4634 7913).

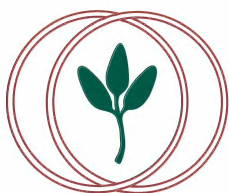
We look forward to seeing you this year in Sydney.

Bob Makinson and Cathy Offord

Co-organisers

Photos: Lotte von Richter, Mount Annan Botanic Garden.

The ANPC 7th National Conference is supported by: Mount Annan Botanic Garden (part of the Botanic Gardens Trust); The NSW Department of Environment & Climate Change; The Hawkesbury-Nepean Catchment Management Authority; Wyndham Estate.



Australasian Plant Conservation

BULLETIN OF THE AUSTRALIAN NETWORK FOR PLANT CONSERVATION INC

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