Department of Primary Industries, Parks, Water and Environment
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Tasmania
Explore the possibilities

Proceedings of the 2007 Buttongrass Moorland Management Workshop

PROCEEDINGS OF THE 2007

Buttongrass Moorland Management

WORKSHOP

Nature Conservation Report 10/4 • Edited by Jayne Balmer

Department of
Primary Industries, Parks, Water and Environment

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PROCEEDINGS OF THE 2007

BUTTONGRASS MOORLAND MANAGEMENT WORKSHOP

A workshop held 4 – 6 July 2007

At the School of Geography & Environmental Studies

University of Tasmania, Sandy Bay, Tasmania.

Edited by Jayne Balmer

With assistance from Jenny Styger and Jennie Whinam

Nature Conservation Report 10/4

ISSN: 1441-0680 (print)

ISSN: 1838-7403 (electronic)

Published by the Biodiversity Conservation Branch, Department of Primary Industries, Parks, Water and Environment, GPO Box 44, Hobart, 7001.

Cover design by Brett Littleton, ILS Design Unit, DPIPWE

Front Cover Photograph: Mosaic of vegetation communities, including buttongrass moorland, Mount Anne, Tasmania, taken by Grant Dixon.

Back Cover Photographs: buttongrass moorland with Mt King William in the background taken by Michael Driessen; discussion between scientists during the buttongrass moorland management workshop field day by Peter Grant; close up of buttongrass flower by Tim Rudman; the Sorrell River and terraces by Kathryn Storey; march fly on buttongrass seed head by Michael Driessen; green mountain lily, an ancient endemic plant species of buttongrass moorland by Tim Rudman.

Cite as: Balmer, J. (ed) 2010, Proceedings of the 2007 buttongrass moorland management workshop. *Nature Conservation Report 2010/4*. Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania.

Preface

An edited extract from the opening speech delivered by Peter Mooney
General Manager of the Tasmanian Parks and Wildlife Service.

The purpose of this workshop is to present and discuss buttongrass moorland values and their management in Tasmania.

Buttongrass moorland may have expanded as a result of the migration to Tasmania by Aboriginal people at least 35,000 years ago. The coastal hinterlands of buttongrass moorlands in western and southwest Tasmania were occupied by Aborigines at the time of European arrival. Buttongrass moorlands were used for hunting game and provided open travelling routes for trade and social exchange. Aborigines actively managed the landscape by regularly burning buttongrass to encourage game and keep the country low and open for ease of travel. Traditional burning practices in buttongrass moorland all but ceased when British Colonial Government policy resulted in the relocation of the native inhabitants of Tasmania to Flinders Island in the 1830s.

Moorlands were not greatly valued by the early colonial settlers. They proved unpalatable for stock grazing and unsuitable for farming. They were wastelands and identified as such on many maps well into the 1970s. As a consequence, relatively little of the buttongrass moorland estate has been alienated to private land tenures.

Reservation of land for recreational and conservation purposes began as early as the 1860s in Tasmania. However it was not until the late 1960s that conservation became a publicly divisive debate upon which governments were overturned. A campaign to stop the flooding of Lake Pedder failed. However the National Parks and Wildlife Service was created in 1971, the same year that the flooding of Lake Pedder began. A decade of intense political debate about the use and management of the western Tasmanian wilderness followed. This culminated in 1982 with the inscription of the area on the United Nations Educational Scientific and Cultural Organisation (UNESCO) World Heritage list. Following this the Australian government joined the Tasmanian government in providing financial assistance to Tasmania for the management of the Tasmanian Wilderness World Heritage Area (TWWHA) — a partnership that continues to this day.

Although about one quarter of the TWWHA is occupied by buttongrass moorland, this ecosystem was not recognised as a significant value in the 1981 nomination of the western Tasmanian wilderness National Parks for World Heritage Area listing. While the world heritage value of this ecosystem has now been recognised, the moorlands are probably still the least appreciated and understood ecosystem in Tasmania.

It is fitting that in the 25th year of the TWWHA our collective information about buttongrass moorlands was presented and discussed at the buttongrass moorland management workshop. This volume, together with the special theme edition of Australasian Plant Conservation (vol 16, no 3, Dec 2007) 'Buttongrass moorland – conservation and management', provide a summary of the talks and discussions held at the workshop. They are intended as a resource to guide future research and management of buttongrass moorland.

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Buttongrass illustration by Richard Hale

Acknowledgments

This report was prepared under the direction of the Department of Primary Industries, Parks, Water and Environment (World Heritage program).

The workshop was supported by funds and in kind support from the Department of Environment & Water Resources' World Heritage Area program (now Department of Sustainability, Environment, Water, Population and Communities), the Tasmanian Parks and Wildlife Service, the Ecological Society of Australia (Tasmanian branch), the University of Tasmania and the Tasmanian Department of Primary Industries and Water (now DPIPWE).

The publication of these proceedings was funded from the Australian Government's World Heritage program, administered by the Tasmanian Department of Primary Industries Parks, Water and Environment.

The workshop organising committee comprised members from the then Department of Primary Industries and Water (DPIW) — Jayne Balmer, Melina Boerma, Michael Driessen, Ian Houshold; the Parks and Wildlife Service (PWS) — Adrian Pyrke; the University of Tasmania (UTAS) — Maj-Britt di Folco, Emma Pharo, Alastair Richardson; and an independent consultant — Mick Brown.

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Introduction

The plant commonly known as 'buttongrass' is a tussock forming sedge with the scientific name *Gymnoschoenus sphaerocephalus*. The vegetation in which this species is usually (but not always) common is also known as 'buttongrass' or 'buttongrass moorland'. Jarman *et al.* (1988) provide a definition of buttongrass moorland vegetation that is adopted for the purposes of these proceedings:

- "any treeless vegetation containing *Gymnoschoenus*, except communities where only a few isolated obviously adventive *Gymnoschoenus* plants are present;
- Vegetation in which *Gymnoschoenus* is common but which contains widely spaced emergent trees;
- Small recurring islands (mostly areas less than about 50 by 50 m) of non-alpine, treeless vegetation which do not contain *Gymnoschoenus* but are surrounded by communities of the type described above; small strips of similar vegetation (about 20–30 m wide) which occur along creeks or in gullies, are also included as buttongrass vegetation providing that the above communities border them on either side." (Jarman *et al.* 1988).

These proceedings comprise the opening and closing presentations, the summaries of the buttongrass moorland workshop group discussions, some of the papers presented, as well as feedback from participants regarding buttongrass moorland management and research. Of those papers and posters not included, most have been published elsewhere (see bibliography below). Many were published together in *Australasian Plant Conservation* volume 16 (issue number 3), the Bulletin of the Australian Network for Plant Conservation. This was a special theme edition: Buttongrass moorland — Conservation and management. The complete collection of abstracts for posters and papers presented at the workshop were printed in the workshop program (anonymous 2007), which is still available on the internet and in selected libraries.

Some additional papers and reviews (not presented at the workshop) have been included in these proceedings because of their relevance to buttongrass moorland management. Poetry is dispersed through this volume in recognition of the importance of the arts to education, protection and promotion of natural values.

The abstracts of the posters and papers presented at the workshop as well as a list of registered attendees can be found in Anon (2007) which at the time of this publication is still available at selected libraries and on the internet.

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A review of fire history in south-west Tasmania

Jayne Balmer, Michael Driessen, Sandra Whight

Introduction

Humans and fire are inimically linked to the evolution of landscape and vegetation in Tasmania. Tasmania's climate has until recently not been conducive to frequent or large-scale naturally ignited fires and so it is assumed that frequent fires in the past were associated with the presence of people (Bowman and Brown 1986). Jones (1969) described the practice of Aboriginal fire-stick farming, in which Aborigines used fire to deliberately promote green-pick for wildlife which they then hunted. The extensive areas of fire-dependent buttongrass moorlands and scrub in western Tasmania have been interpreted as evidence for a history of frequent anthropogenic firing since the arrival of people (Jackson 1968, Marsden-Smedley 1998, Jackson 1999).

The currently accepted estimate for human arrival and occupation of Australia is between 60,000 and 40,000 years BP and assumes a single immigration from the Sunda shelf (Roberts *et al.* 1990). Alternative views include the possibility of as many as three immigrations beginning before 100,000 years BP, but evidence for these alternatives is controversial (Flannery 1994).

The last interglacial period prior to the current Holocene interglacial ended about 100,000 years BP. This was followed by the Margaret Glaciation, which was most extreme between 30–13 ka (LGM~22 ka) but included an early ice period at about 70–60 ka followed by a major interstadial with the coldest period between 45–20 ka. During part of this cold-arid glacial period the sea-level was sufficiently low to uncover a land-bridge between Tasmania and mainland Australia. However, the earliest widely accepted date for Aboriginal occupation in Tasmania is 35 000 years BP (Cosgrove 1995, Flood 1995, Allen 1996, Bowdler 2010). More recently the base of an occupation site on the Jordan River levee in eastern Tasmania provides evidence for the presence of Aborigines as early as 37 500±3,800 years BP (Paton 2010).

Pleistocene vegetation

Pollen data from the Darwin Crater and elsewhere provide evidence that Tasmanian vegetation became more open from as early as 70,000 years BP (Colhoun and van de Geer 1988, 1998, Jackson 1999). In New Zealand where the climate followed a parallel trend to that of Tasmania, vegetation did not become significantly more open but followed the same pattern of change as previous glacial and interglacial cycles (Nelson *et al.* 1986, Jackson 1999). Other trends in the pollen such as a decline in more fire sensitive genera such as *Allocasuarina* and increases in fire tolerant genera such as *Eucalyptus* correspond to increases in charcoal frequency and provide evidence that there was an increase in fire frequency before the earliest date for Aboriginal occupation in Tasmania (Jackson 1999). This led Jackson (1999) to suggest that people may have arrived in Tasmania during a much earlier land bridge event. Uncertainties in aging soil profiles and the absence of archaeological evidence for Aboriginal presence prior to 42,000 years BP prevents acceptance of Aborigines arrival significantly before about 40 ka.

Mooney *et al.* (2010) argue that there is no evidence in the sedimentary charcoal records from Australasia for a significant change in fire frequency that can be linked to the arrival of people (50±10 ka) in Australia. They contend instead that fire frequency is linked to climatic variation.

Late glacial and Holocene (pre-European)

From their arrival in the Pleistocene up until 13 ka Aborigines in Tasmania lived along inland lowland river systems in the wetter western and southern parts of Tasmania, surviving the last glacial maxima in limestone caves and hunting game for their subsistence (Bowdler 2010). If they also made use of the coastal margin during that period the evidence has probably been removed by rising sea-levels. The western Tasmanian was cold and arid during the glacial and the landscape was dominated by grasslands and subalpine and alpine shrublands (Hope 1978, Macphail and Colhoun 1985, Macphail 1986).

The early Holocene brought warmer and wetter conditions favouring the expansion of forest from riparian refugia. Some sites, once recolonised by rainforest, remained vegetated by rainforest or rainforest scrub from early Holocene colonisation to present (e.g. the middle slopes of Frenchman's Cap and montane sites on Mt Read, the Tyndall and Denison Ranges, Macphail 1986, 2010).

Fletcher and Thomas (2007b) successfully use classification and ordination to discern the local vegetation communities from modern pollen samples, despite the dominance of regional pollen of rainforest tree species. They applied this technique to a fossil pollen sequence taken from core samples from a lowland pond between Lake Pedder and Mt Anne. This revealed that buttongrass moorland has dominated the local environment at the core site for the entire Holocene (10350 ^{14}C yr BP to present). Their analysis showed that temperature increased through the late Glacial and early-Holocene, reaching a peak in the mid-Holocene and has been declining since. They contend that the high carbonized particle content throughout the core proves that fire was a constant and frequent feature of the site from the late glacial to the present.

Forests were absent from the region during the early Holocene but as the climate warmed *Pomaderris apetala* dominated wet forests and *Phyllocladus aspleniifolius* dominated rainforests appear in the region followed slightly later by *Nothofagus cunninghamii* rainforests (9550 and 7500 ^{14}C yr BP, Fletcher and Thomas, 2007a). Fletcher and Thomas argue rainforests were never present in the local area of their core site and that it was never common even in the regional landscape because of extensive and frequent anthropogenic firing. They concurred with others that during the later part of the mid-Holocene the abundance of rainforest taxa declined, a decline that commenced as temperatures peaked. Macphail (1979) observed that the decline in rainforest taxa during the late-Holocene was concurrent with a decline in rainfall and was associated with an increase in the importance of *Eucalyptus* and Poaceae. Fletcher and Thomas (2007a) agreed with Macphail (1979) and Margraf *et al.* (1986) that climate change was the most likely cause in rainforest decline during the late Holocene, noting that an increased importance of *Bauera* and *Leptospermum* at the expense of *Melaleuca squamea* in the buttongrass moorland vegetation reflected a lower effective precipitation. They rejected an alternative suggestion by Colhoun (1996) that nutrient leaching may have led to the decline of rainforest species and explained the expansion of sclerophyllous species.

Macphail (2010) debates several aspects of Fletcher and Thomas's interpretation. He observes that there may be a hiatus in their soil profile leading to inaccuracies in the dates and interpretation of vegetation change for the site. He warns that interpretation of charcoal is fraught with difficulty and that the analysis of a single lowland core does not provide sufficient evidence for the generalisation that buttongrass moorland dominated the entire southwest region for the entire Holocene. He points out that this generalisation fails to explain the withdrawal of Aborigines from the limestone river valley caves which has been attributed by others to the expansion of rainforests (Kiernan *et al.* 1983). Further-more he observes that *Gymnoschoenus*-type pollen is present in highland cores as early as 14–17 ka BP, suggesting it may be wind dispersed over a greater distance than assumed by Fletcher and Thomas.

While acknowledging Macphail's (2010) warnings, it may be reasonable to accept that there is a body of evidence that supports the theory that anthropogenic firing combined with an associated change in soil conditions (Colhoun 1996, McIntosh *et al.* 2005, Macphail 2010) enabled the replacement of grasslands and alpine vegetation with buttongrass moorlands in many areas of lowland southwest Tasmania. However it is also probable that the warm wet condition of the early-Holocene enabled the rapid expansion of rainforest beyond its current distribution in areas where:

- burning was not undertaken (especially inland and highland regions);
- there were barriers to fire spread (rivers and existing refugial rainforest patches);
- soils were particularly fertile (limestone river valleys).

The Aboriginal population was probably never larger than several thousand (Bowlder 2010). Archaeological evidence from coastal middens and camp sites around Tasmania suggests that from 13000 years BP until European arrival, Aborigines became heavily dependent on a coastal economy and lifestyle (Bowdler 2010). Nevertheless there is evidence from early European settlers that suggests Aboriginal Tasmanians were at least seasonally active in much of south-western Tasmania in the early 1800s (Marsden-Smedley 1998, Macintosh 2005), and were not exclusively coastal dwellers. Further research in inland sites of southwest Tasmania is needed to determine to what extent these people continued to occupy and burn inland areas (Macphail 2010).

King (2004) has used computer-based fire and vegetation simulation modelling to investigate the likely the relationship between historical burning regimes and vegetation processes in south-west Tasmania. Her work (King 2004) provides evidence that:

- lightning ignited fires have been significant in establishing the existing pattern of vegetation distributions — buttongrass occurring in areas with a high frequency of lightning and rainforests occurring in areas of a low frequency of lightning;
- lightning and Aboriginal burning alone would be insufficient to convert a rainforested landscape into one with the current extent of buttongrass, the most likely explanation for the current extent of buttongrass is that Aboriginal firing restricted the expansion of rainforest following the last glaciation;

Although King's work (2004) did not attempt to take climatic variation into account she noted that it is extremely likely that climatic variation (such as experienced since the mid-Holocene) would have had a profound influence on burning frequency and extent.

No one knows what the actual frequency of Aboriginal burning used to be. Jackson (1968) suggests moorland and scrub will be maintained with average burning intervals of between 25 to 50 years. Evidence from aging buttongrass moorlands suggests that in some low fertility situations this vegetation is able to persist with fire-free intervals over 100 years in highland areas and over 50 years in some lowland areas (Jarman *et al.* 1988a). The reason for difference between lowland and highland ages may be due to the greater distance from ignition sources with few (or more recent) roads in highland areas. However reduced number of days when the vegetation will burn at this altitude may also contribute to the difference.

In fertile situations succession to scrub and forest is likely to be more rapid. King (2004) noted that in her computer simulation trials that fire frequencies were higher in lower fertility areas, making succession more likely to occur in higher fertility areas.

Marsden-Smedley and Kirkpatrick (2000) surmised that the Aboriginal fire-regime was one of frequent (intervals of less than 20 years between fires), low-intensity moorland burns conducted for the most part during spring, autumn and dry periods in winter. With such frequent moorland burning they argue that fires would only have infrequently extended into eucalypt forest and rarely occurred in rainforest and alpine vegetation (Jackson 1968). However there is evidence from the observations of European settlers and early explorers that at least some fires presumed to be lit by Tasmanian Aborigines were lit in summer (Stockton 1982). There is also ample evidence that both large and intense fires, sufficient to burn large areas of eucalypt forest, peat and cause major erosion, did occur in Tasmania before European arrival (McIntosh *et al.* 2005, 2009).

Post-European fire history

Traditional Aboriginal burning practices all but ceased with the removal of most Aboriginal people from western Tasmania by 1833. The early period of European land-use in south-west Tasmania (circa 1830s –1930s) was characterised by periods of no burning followed by large high-intensity fires in all vegetation types (Marsden-Smedley 1998; Marsden-Smedley and Kirkpatrick 2000). These fires were lit for the primary purpose of opening up the region for exploration (particularly mineral exploration), and in the mistaken belief that the moorlands could be converted into productive pasture-lands (Marsden-Smedley 1998).

Between 1940 and 1970 fire regimes in south-west Tasmania reverted to low to medium intensity moorland fires as the area became increasingly valued for its natural and scenic values (Marsden-Smedley 1998). After 1970 there was some planned burning undertaken to reduce fuel loads in selected areas by various government agencies including the Parks and Wildlife Service, the then Forestry Commission and the Hydro Electric Commission. However there was an effective exclusion of fire (including an active suppression of wildfire) across the remainder of the region (Marsden-Smedley and Kirkpatrick 2000). Burning for ecological purposes commenced in the 1980s. Two fires in the 1980s burnt nearly 60,000 ha of south-west Tasmania. The first was an escaped planned burn for orange-bellied parrot habitat fire at Birchs Inlet which burnt 36,000 ha while the second was an arson started fire in 1986 that burnt 23,500 ha near the De Witt Range. Relatively little forest vegetation was burnt in either of these fires.

In the 1990s, planned burning in buttongrass moorland became more restricted. Strategic fuel reduction burning occurred along the Lyell Highway and in restricted areas of the Central Plateau Conservation Area. Small-scale ecological-management burning was undertaken for orange-bellied parrots at Melaleuca and Birchs Inlet. Over this period, an average of about 150 ha/year were burnt for ecological-management and 170 ha/year for fuel reduction (Marsden-Smedley 2004).

In the last decade there have been over 70 planned burns completed in south west Tasmania. Planned burning has been undertaken for multiple objectives: ecologically to increase the diversity of moorland ages; and strategically to reduce the risk of landscape scale fires. In total over 22,000 ha of buttongrass moorland has been burnt since 2000 during planned management fires (Parks and Wildlife Service unpublished data). This included ‘unbounded patch burning’.

There have also been several wildfires, including two large ones, in south west Tasmania in the past decade which were ignited by lightning. In February 2007 the Reynolds Creek fire burnt more than 23,000 ha, and the Cracroft Plains fire burnt over 12,000 ha. Two smaller fires at Birchs Inlet and Mount Castor each burnt approximately 2,500 ha. Seventy percent of the area burnt by these fires was mapped as buttongrass moorland, while only 6% was mapped as rainforest (Wood *et al.* in press).

Current fire management

Within the PWS there have been structural and administrative changes, and the development of clearly defined policies and procedures for all aspects of fire management. At an inter-agency level, new prescriptions and guidelines for planned burning in Tasmania have been prepared (Marsden-Smedley, 2009). The prescriptions limit the weather conditions under which fires may be lit, but do not prescribe fire regimes. The prescriptions provide a minimum accepted standard for land managers and fire crews to comply with, but they do not prevent the adoption of additional measures to further mitigate-against potential impacts on natural and cultural values for specific areas and planned burns.

There is no current fire management plan covering the entire WHA. The southern part of the WHA is included in the PWS Southern Region Strategic Fire Management Plan (SFMP). A draft proposal for fire management in the WHA was prepared by Marsden-Smedley (2004) however this was never endorsed. It nevertheless provided guidance for annual burning programs. For south-west Tasmania, planning is undertaken by both Southern and North-West regions.

All planned burning programs are now made on the basis of a risk assessment, which subsequently determines broad fire management zones, detailed through a strategic fire management plan. Southern Region has an approved SFMP (DPIPWE, 2010) in place, and a draft plan for the North West Region is expected to be completed by the end of January 2011.

Future fire-management

The PWS has moved away from reserve specific plans, and developed a new approach, undertaken at a landscape scale. This new system comprises strategic fire management plans for Tasmania's three regions (Northern, Southern and North West), which provide the framework and direction for regional operational plans.

At the crux of each strategic plan is the bushland risk assessment model (BRAM) which is used to evaluate fire risk and consequence of fires to values and assets from which fire management zones are then mapped. Four principle fire management zones are adopted. The asset zone is managed for the protection of assets, and in general will not be subject to planned burning for fuel management purposes and will be prioritised for fire suppression in the event of a threat from wildfire. The asset protection zone comprises regions around assets which will be managed to reduce the threat from wildfire to assets. Areas zoned as asset protection may include roads, fire trails and fire breaks. These areas may be subject to intensive fuel management and the management of fuels will take precedence over other management issues (e.g. view-field management, cultural or biodiversity management issues). The strategic fuel management zone includes areas managed to reduce the likelihood of wildfires reaching sizes in excess of 5000 hectares. Within these areas fuels may be managed with frequent planned burning. The land management zone will be managed to maintain and protect natural and cultural values using fire only as required for ecological management.

Fire regimes (fire interval, size, patchiness etc) are defined within the operational plans and may be uniquely prescribed for particular areas or vegetation types. The new guidelines for planned burning (Marsden-Smedley 2009) contain some information on recommended burning regimes.

The potential impact of climate change on intensity and frequency of fires is being studied through monitoring programs. As well as the increase in lightning strikes, there are also concerns regarding the flammability of vegetation types that would not normally burn — in particular some rainforest communities, and alpine and sub-alpine communities. Fire is considered to be an increasing threat in these communities made vulnerable by climate change impacts.

Wildfires in western Tasmania from 2003 to 2008 burned approximately 130,000 ha (Pyrke p. 73, this volume), including some rainforest. The incidence of lightning ignitions causing wildfires in south-west Tasmania is increasing. Climate change forecasts suggest this trend is likely to continue.

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Haiku

Meika Loofs Samorzewski

Snip rot meals belie
Parrot appeals to moor land
To fire, Track? What track?

A review of the potential interactions between fire, soil, hydrology and geomorphology of buttongrass moorland.

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Introduction

Large-scale fires influence many physical processes in all landscapes where they occur, potentially resulting in significant changes to geomorphology, soil and hydrology (Shakesby and Doerr 2006). This paper is a discussion of the mechanisms by which fire can cause such changes, with a particular emphasis on features typical of Tasmania's buttongrass moorlands. This is not an attempt to define an appropriate fire regime for moorlands. Nor does it delve into the complex issue of how climate change will alter existing relationships between landscape and fire. It is not a comprehensive review of the huge fire related literature. Rather, it presents a brief overview of the topic based partly on the published literature and partly on the author's research and observations. The intention is to increase the understanding of those working in the field of the influence of fire on physical landscape processes.

Also presented here are the existing recommendations for managing planned burning in buttongrass moorland where it may impact upon the landscape. These recommendations are mostly outcomes of research into fire – moorland interactions. They are generally based on the precautionary principle, and seek to avoid damage to moorland landscapes and surrounding conservation values. Their effectiveness is mostly untested. They may be addressed in fire management plans or during pre-burn planning for an individual fire or area, at the discretion of the staff involved. They are not prescriptions. Existing operational prescriptions for burning in buttongrass moorland relate to factors influencing the potential for fire to escape (e.g. weather conditions and the soil dryness index), rather than being designed to protect in-situ conservation values (Forestry Tasmania 2005, Marsden-Smedley 2009).

Both wildfires and management burns have the potential to impact on moorland. Priorities for management burning and wildfire suppression are presently influenced more by the distribution of fire sensitive values adjacent to moorland, rather than by the potential impact of fire on the moorland itself. This is in part because of the great difficulty of controlling wildfires within all but recently burnt moorland areas, and in part because of the perceived robustness of the ecology of moorland areas to fire.

Fire undoubtedly influences geomorphic and soil features and processes. It is also a natural component of the Tasmanian buttongrass moorland landscape. To some extent the physical features of moorland areas have the form that they do because of their fire history. Therefore, fire is not necessarily detrimental to the physical conservation values of an area, and can potentially be beneficial.

A significant change in fire regime has the potential to alter many aspects of geomorphology across a large spatial scale. Fire that is too frequent can increase (e.g. sediment production) or decrease (e.g. peat formation) landscape process rates, so that they are outside the long-term rates and magnitudes of change for the area. The nature of processes may also change (e.g. switch from forming organic to mineral soils). Fire that is too intense can cause catastrophic loss of soil and associated landscape instability. Too infrequent burning in a landscape adapted to fire will also change rates and character of landscape processes, and could cause the loss of fire related features.

Estimation of the impact of a fire regime must be considered in terms of both the magnitude and frequency of fire. To use ongoing peat formation as an example, it is possible that very frequent low magnitude fires could slow or completely stop formation of new peat. In the long term, it is conceptually possible that this could have a greater impact on the soil and the ecosystem it supports than a very infrequent, more intense fire that results in some peat combustion.

Fire has the potential to affect soils, hydrology and geomorphology. These effects are interactive, but for simplicity are described separately below.

Figure 1. An area of moorland on the lower slopes of the Western Arthurs that burnt in the wildfire of 2007. These gravelly skeletal soils may once have had organic horizons that have been lost due to combustion, mechanical erosion and decomposition following this and earlier fires. Photo by Grant Dixon.

Soil

The soils of buttongrass moorlands are typically high in organic material in their surface horizons (Jarman *et al.* 1988). The character of the soil varies, depending on numerous factors including the nutrient status of the underlying substrate, hydrology, topography, character of the vegetation, and fire history. The typical pattern is of an organic-rich, fibrous surface horizon over a second organic-rich lower horizon that is significantly more humified (Pemberton 1989). This may be (although not always) underlain by mineral horizons of variable depth. In some cases, organic horizons may be absent, with the moorland vegetation underlain either by a deep mineral soil profile, or by a skeletal gravelly soil. Soil profiles of any type may be underlain by bedrock or by deposits of periglacial, glacial or fluvial origin.

Impacts of fire on the soils of buttongrass moorland landscapes include soil loss through combustion, loss of soil post-fire due to mechanical erosion (e.g. wind, sheet or channelised flow, frost heave, soil creep), changes to soil properties (e.g. soil wettability, cohesiveness and erodibility), loss of soil post-fire due to increased decomposition rates, and changes to peat accumulation rates. For a fire regime to be sustainable, any loss of soil needs to be compensated for by soil formation between fires. This might be in the form of incorporation of new organic material, developing mineral soils by weathering substrates, or by the incorporation of deposited sediments.

Fire may also influence soil hydrology, but this is discussed separately in the Hydrology section.

Soil loss through combustion

Combustion of the organic component of soils will occur when soil temperatures reach 270 – 400°C, and where oxygen is available (Shakesby and Doerr 2006). In peat, because the organic content is high, the soil profile can ignite and burn slowly for extended periods, so long as soil moisture is low enough. The potential for this to occur depends partly on soil organic content and moisture content. Marsden-Smedley (1993) found that soils with less than 27% organic material would not support combustion, while soil with very high organic content (88%) could sustain combustion when moisture content was up to 68%.

Ignition of organic soils is more likely to occur where dead plants, particularly roots, lead fire down into the profile, or where the organic soil is better drained such as on small rises, exposed margins of peat along rocks, or previously eroded edges (Marsden-Smedley 1993; Pemberton and Cullen 1995). Macro-pores such as crayfish burrows may also have the potential to lead fire into the soil. Pemberton and Bridle (2003) suggest that even under ideal burning conditions peat can smoulder on the side of buttongrass tussocks.

Combustion of the soil can lead to truncation of the organic soil profile (Pemberton and Cullen 1995). Surface layers of the organic soils associated with buttongrass moorlands are often more fibrous with higher organic contents than lower horizons, which means that they have greater potential to burn. Such a fire could potentially cause an immediate reduction in soil depth, and change in soil properties, but may still leave some organic rich soil at the site. Research in the United Kingdom has found that soils exposed to repeated fires (burnt every ten years) have significantly lower carbon contents than unburnt soils (Garnett *et al.* 2000). To what extent this was caused by combustion or by increased rates of decomposition is not clear. The extent to which partial combustion of the soil profile has occurred in buttongrass moorlands is not known, although cases of such losses have been reported (e.g. Bowman and Jackson 1981).

There is also the potential for complete loss of organic horizons (Pemberton and Cullen 1995). Moorland soils vary in their carbon contents (di Folco 2007), with some areas below the threshold for supporting combustion identified by Marsden-Smedley (1993). Soils with sufficient carbon content for combustion do occur, and there are known examples of the loss of entire peat profiles over large areas, for example at the Lost World Plateau in 1975/76 (Pemberton and Cullen 1995). Small patches of combustion such as those shown in Figure 2 are also common following hot fires.

Figure 2. A patch of ash showing where soil has been burnt in the Heemskirk fire of 2008. Photo by Michael Comfort.

Previous work has made the following recommendations to reduce the potential for combustion of peat:

- Burn only when the Soil Dryness Index is less than 10 (Marsden-Smedley *et al.* 1999).
- Use field based assessments of soil moisture, as Soil Dryness Index does not work well for peat soils (Marsden-Smedley 1993; Bridle *et al.* 2003).
- Avoid burning areas where there is evidence for past soil loss, such as extensive gravel or bedrock outcrops, soil pedestals and truncated peat profiles (Pemberton and Bridle 2003).
- Avoid burning areas where peat soils are likely to dry out, such as on slopes over 15°, or where the peat is underlain by a free draining sandy or gravely substrate (Pemberton and Bridle 2003).
- Avoid burning where there is dead vegetation and dry peat edges that can provide access for the fire into the soil (Pemberton and Bridle 2003).
- After a fire, use aerial assessments with on ground follow up to identify areas of smouldering peat, and take appropriate steps to extinguish them (Pemberton and Bridle 2003).

Soil loss and movement due to mechanical erosion

Soil can be eroded by wind, water (e.g. rainsplash, frost heave, sheetwash, rill erosion and gully erosion), and mass movement (e.g. soil creep and mass failure). Large bodies of research from a range of environments has shown that fire can increase the rate of all of these (Shakesby and Doerr 2006). Destruction of the vegetation and litter leaves soil exposed to wind and water. Also, heating of the soil surface changes soil properties in ways that generally makes it more erodible (see changes to soil properties below). The most extreme case is combustion of the organic component of the soil, which leaves ash that is very easily removed by wind and rain. As discussed in the hydrology section, overland flow volumes often increase after fire, increasing the effect of sheet erosion on bare surfaces. At higher elevations, erosion by needle ice may also be a problem in bare ground. An increase in mass movement such as soil creep and shallow landslides may occur over an extended period after fire due to decreased soil strength as roots of plants partially or completely killed decompose.

Work in Tasmania has linked fire to increased rates of soil erosion (Pemberton 1986, 1988, and 1989; Pemberton and Cullen 1995). For example, sheet and gully erosion has been documented in the area between Birches Inlet and the Wanderer River, where "peat horizons have been removed by wind, water and fire" (Pemberton 1988 p 111). In this location, about 43% of the mapped area has been eroded. Unfortunately, although some data has been collected by di Folco of the University of Tasmania, there is not yet any published data available on rates of any of the erosion processes described above in a Tasmanian context.

The degree of soil damage depends on the intensity and frequency of the fire. Where only the vegetation is damaged, leaving surface litter intact, soil loss is likely to be small. Where all the vegetation and litter is removed, some soil loss to mechanical erosion should be expected. Where this occurs frequently, there may be considerable soil loss. Where combustion of the soil occurs, this destroys the vegetation and the soil seed bank. As a result vegetation recovery is likely to be slow, extending the time over which mechanical erosion can operate (Pemberton and Cullen 1995).

Where a thatch or litter layer remains following fire, this is likely to reduce mechanical erosion by preventing the soil surface from drying out, and protecting it from wind and water. It may also aid seedling establishment (Marsden-Smedley 1993). However, this thatch represents a major fire hazard in the following years, as it has the ability to carry fires with a high rate of spread (although this is combined with low fire intensity) (Marsden-Smedley 1993). Fires of sufficient intensity to burn thatch may have deeper flame depth, and leave areas of smouldering fuel behind the fire front (Marsden-Smedley 1993). It is not clear if this has the potential to lead to combustion of the soil surface, but this seems possible under the appropriate soil moisture conditions.

There is no data on the effect of the death and decay of roots following fire on the frequency of mass movements such as soil creep and mass failure in buttongrass moorland landscapes. It is not clear to what extent root death may occur, given that many components of moorland vegetation will survive a moderate intensity fire and reshoot. However, given the loss of above ground biomass, some associated root death could be expected to follow. The author has some observational evidence of stream bank erosion caused by root decay. Although in a different context, mass failures have been frequently observed in peat on Macquarie Island following destruction of vegetation by rabbits (Scott 1988).

The following recommendations have been made to reduce the potential for mechanical erosion of peat soils:

- Avoid burning on slopes over 15°, as these will be prone to erosion (Pemberton and Bridle 2003).
- Aim to leave a litter layer on the ground after the fire, as this will reduce erosion (Pemberton and Bridle 2003).

Marsden-Smedley (1993) described conditions which resulted in different levels of thatch combustion:

- Little thatch remained when temperature was above 12°C, relative humidity below 60% and soils were relatively dry.
- Moderate amounts of thatch remained when temperatures were between 9 and 11°C, and relative humidity between 60 and 75%.
- Extensive thatch was left when temperature was below 8°C, relative humidity above 75% and soils wet (i.e. standing water).

Changes to soil properties

The heating and removal of vegetation and surface soil layers that occur in a fire have the potential to change soil properties. Researchers across a range of environments have found that fire results in a soil that is more friable, less cohesive and more erodible (Shakesby and Doerr 2006). This can be the case even after low intensity fuel reduction burns (Hall 1994).

Beyond the work of di Folco (2007) and Bridle *et al.* (2003), there is little documented information on changes in character of buttongrass moorland soils following fire. Surface soil may develop water repellency after fire, depending on the temperature and duration of the burn (Shakesby and Doerr 2006). Water repellency has the potential to have long term effects on soil hydrology, which may have flow on effects on decomposition of organic horizons (discussed below), and revegetation rates. It can also affect catchment hydrology (also discussed below). Regardless of fire history, organic soils are water repellent when dry (Egglesmann *et al.* 1993). As soil surfaces left bare by fire may dry out more readily than fully vegetated surfaces, this may also lead to the development of water repellency after fire. Also, charcoal and ash can block soil pores following fire, further reducing infiltration rates. There is anecdotal evidence of water repellency of moorland soils following fire. At this stage, there have been no measurements made of the development of water repellency in moorland soils after fire, or of the longevity of that water repellency.

Soil nutrients have been shown to change following fire on organic moorland soils (Bowman and Jackson 1981). Bridle *et al.* (2003) showed that at Airstrip Road, a site north of Mt Wedge, soil concentrations of nutrients usually stored in plants increased after fire, while elements held in the soil profile showed little change. Bridle *et al.* speculated that there were more nutrients available to be mobilised after fire, and the downslope sites received nutrients from burnt areas in their catchments. There does appear to be potential for long term changes to nutrient status of soils in response to fire regimes.

Previous work has made the following recommendation to reduce the potential for changes to soil properties:

- Aim to leave a litter layer on the ground after the fire, as this will reduce drying of the soil surface (Bridle *et al.* 2003).

Increased peat decomposition rates

The removal of vegetation and litter by fire has the potential to cause an increase in the rate of decomposition of the organic component of the soil. Because this can be a large proportion of soil mass, decomposition can potentially result in significant soil losses, and a change in soil character. In part, decomposition converts organic particles into dissolved organic matter that can then be exported from the catchment in the stream system (Worrall *et al.* 2002; Worrall and Burt 2004).

Decomposition will speed up with increasing soil temperature, and with increasing oxygen availability. Increased nutrient availability may also increase biological activity in the soil. After fire, bare, black soil surfaces are readily heated by the sun. di Folco (2007) has demonstrated burnt areas can have much higher soil temperatures than unburnt areas, particularly during summer. Fire can also increase the concentration of some soil nutrients. Finally, bare burnt soil surfaces may desiccate more easily, and re-wet more slowly than fully vegetated soils (see discussion of soil properties above). As the soil dries out, oxygen can permeate the material, increasing decomposition rates. Soil cracks may also develop on desiccation, and allow oxygen to diffuse more rapidly into the soil profile (Bridle *et al.* 2003). Studies elsewhere have found that decomposition rates are higher under burnt than unburnt plots (e.g. Jeffries 1986 in Bridle *et al.* 2003). These issues were investigated by Bridle *et al.* (2003) in the Airstrip Road study. They found no significant impact of fire on decay rates or root productivity, but suggested that this may have been because sample sizes were too small to detect any effect.

Recommendations to reduce the potential for increasing decomposition rates in organic soils have been made by previous workers:

- Conduct management burns in autumn so that bare ground has the chance to develop some vegetation cover before summer. Bare peat surfaces will heat up significantly in summer (Pemberton and Bridle 2003).

- Aim to leave a litter layer on the ground after the fire, as this will reduce drying of the soil surface (Pemberton and Bridle 2003).

Changes to peat accumulation rates

Peat forms from dead plant material, and can be developed from roots or above ground plant matter (Bridle *et al.* 2003). Rates of peat formation are uncertain, but are likely to be slow, in the order of 1 to 2 cm per century (Pemberton and Cullen 1995). Fire can potentially influence rates of peat formation by destruction of plant litter prior to its incorporation into the peat profile, and by its effects on plant productivity (Bridle *et al.* 2003). Research in the United Kingdom has found that burning a blanket moorland every 10 years did measurably reduce organic content of peats, which was in part attributed to a reduction in accumulation rates (Garnett *et al.* 2000).

At present, there are no successful direct measurements of rates of peat formation in buttongrass moorlands on management timescales. It is possible that under present climatic conditions, many moorland peats are no longer accumulating new organic material. Bridle *et al.* (2003) investigated these issues at Airstrip Road and found that both above and below ground plant productivity were very low. They found that in the short term, fire contributed to production of loose litter by severing connections with living plants. However, litter decay (and therefore incorporation into the peat profile) was extremely slow. This is a very low nutrient study site, which probably contributed to low rates of production and decomposition. However, fires at high frequency and intensity would remove much of the surface litter before it could be incorporated into the soil, and so prevent continuing peat formation. It is not clear what effect frequent fires may have on root productivity. This may be important, as there are indications that the majority of organic material in moorland soils appears to be root material (di Folco, pers. comm). The work of Bridle *et al.* and di Folco needs to be extended to investigate these questions further. There is also potential for more research to be done in Tasmania with well dated high resolution sediment cores to investigate accumulation rates of organic material, and also to examine historical fire frequency using charcoal counts.

Previous work has made the following recommendation to reduce the impact of fire on present rates of peat accumulation:

- Adopt a burning interval of between 20 and 30 years (Bridle *et al.* 2003). This may allow peat accumulation to occur between fires.

Hydrology

Hydrology refers to the manner in which soils, ground water, streams and entire catchments interact with water. The different components of hydrology interact, and operate at scales from square metres to many square kilometres. Large-scale fire can impact hydrology at all levels, from individual soil profiles through to entire catchments. It does this through its effect on soil properties, and by removing vegetation and so changing rates of evapotranspiration, rainfall interception, canopy storage, and infiltration (Shakesby and Doerr 2006). Changes to hydrology affect geomorphic rates of change in the burn area, and also waterways that have had a significant proportion of their catchments burnt.

Changes to soil hydrology

Soil hydrology reflects the influence of local vegetation and litter, soil surface properties, soil profile properties and the upslope catchment. Moorland soils have some very distinctive hydrological characteristics. To the knowledge of the author, there have been no investigations of the effects of fire on these characteristics.

Local vegetation and litter intercept and trap a proportion of rainfall. This water may drain slowly down to the soil surface, or it may be held in the vegetation until it evaporates, in which case it has no further role in soil and catchment hydrology. All fires destroy a proportion of the biomass available to intercept rainfall, and thus increase both the amount of water reaching the soil surface and the rate at which it does so.

Water that reaches the soil surface can potentially infiltrate the soil. If the soil is already saturated, or if the rain arrives at a faster rate than water can infiltrate the soil, then it will either be stored in temporary ponds on the soil surface, or form overland flow. Reduced ground cover can allow water to flow more efficiently across the soil surface, reducing the time in which infiltration might occur. As discussed above, both fire and post-fire drying of the soil surface can cause water repellency, which reduces infiltration rates. Infiltration rates may also be reduced after fire if bare soil surfaces are compacted by raindrop impact, soil pores are blocked by fine ash, dust or charcoal , or an algal or fungal crust develops that impedes water movement (Shakesby and Doerr 2006). Should the fire burn the uppermost fibrous horizon of the organic soil, this would expose the underlying muck peat which is likely to have much lower infiltration rates. In extreme cases, low infiltration rates can mean that all the water from a rain event runs off, and the soil profile does not receive any water at all (Shakesby and Doerr 2006).

Water that infiltrates the soil profile is either stored in the soil, moves through the soil matrix as throughflow, or moves through preferential pathways and macropores such as root voids, yabbie burrows and soil pipes. Generally, water moves faster through pipes and other preferential pathways, and more slowly through the soil matrix, especially where the soil is a highly humified muck peat. Hydraulic conductivity in a muck peat may be as low as only 8.6 mm per day (Letts *et al.* 2000). In moorland soils, significant throughflow usually occurs in gravels or regolith beneath the organic horizons, as these have much higher conductivity. Fire can affect the movement of water by destroying the more fibrous surface peat horizons where water can flow more rapidly. It is also possible that after fire, increased sediment loads within the soil profile could block macropores and soil pipes.

Finally, water is lost from the soil profile to evapotranspiration, which includes evaporation from the soil surface and plant transpiration. Fire has the potential to increase evaporation by creating bare soil surfaces, and decrease transpiration by removing vegetation.

It is clear that fire has the potential to cause large scale changes to soil hydrology, but the extent to which this occurs in buttongrass moorland, and the length of time post-fire that the effects may be maintained are both unknown.

No recommendations have been made specifically to reduce the impact of management burns on soil hydrology, although recommendations that aim to reduce impacts on soil properties and decomposition rates may also be relevant here.

Changes to shallow groundwater hydrology

Shallow groundwater refers to water stored in the saturated zone of the soil and sediment or weathered rock that underlies the soil. The surface of the shallow groundwater is known as the watertable. The level at which the watertable occurs varies throughout the year in response to variations in rainfall. In a wet winter, the watertable may be close to or above the soil surface in many areas, while in a dry summer it may occur well below the soil profile. Groundwater is recharged by water moving down through the unsaturated part of the soil profile until it reaches the water table. A rising watertable driven by rain in the catchment can also act to re-wet the soil profile. In buttongrass moorlands, this system is complicated because the low hydraulic conductivity of muck peat can act as an aquitard, preventing the movement of water down to the saturated zone, and also confining the watertable and preventing it from reaching the surface.

Catchment scale fire has the potential to influence shallow groundwater hydrology largely through its influence on soil hydrology described above. It is possible that fire could reduce groundwater recharge, by reducing infiltration rates so that more water is transported by overland flow directly to stream channels and so out of the catchment.

As a result, the water table in these areas will be lower than before the fire. Alternatively, water tables could rise after fire. This would in part be due to the reduced evapotranspiration effects described above because of the loss of vegetation. Also, in areas where there are frequent large macropores leading through the soil to the watertable, the proportion of water that reaches the water table might increase because of more efficient runoff and less water being stored in the soil matrix.

Bridle *et al.*'s (2003) work has investigated some of these issues. They found no detectable effect of fire on watertable depth, but the project was plagued with data logger problems and thus its power to detect change was small. Also, for this experiment, only small blocks of vegetation were burnt. The full effect of fire on soil hydrology will only be apparent when an entire catchment is burnt. Other work has shown that following fire the variability of water table depth increases, although average depth may be similar to unburnt areas (di Folco, unpublished data).

No recommendations have been made specifically to reduce the impact of management burns on shallow groundwater hydrology, although see the sections on reducing impacts on soil properties and decomposition rates for recommendations that may also be relevant here.

Changes to stream hydrology

The changes to vegetation, soil and shallow groundwater hydrology described above also cause changes to stream hydrology. Research in other environments shows that after catchment-scale fire, there can be an initial increase in base flow (stream flow during dry weather), attributed to a decrease in evapotranspiration (Shakesby and Doerr 2006). It is also possible for base flows to decrease because reduced infiltration and soil storage capacity means that a smaller proportion of the rainfall is stored and delivered gradually to the channel (eg Conway and Millar 1960). Flood flows typically show a much larger increase, with peak flows occurring faster during rain events, and being up to two orders of magnitude larger than pre-fire (Shakesby and Doerr 2006). This increase is caused by the greater efficiency with which overland flow delivers rainwater to the stream network, and the reduction in the proportion of water intercepted by vegetation. Where riparian vegetation has been burnt, this may also increase the speed of flood waters by reducing bank roughness. The length of time that these effects persist is variable, but they generally attenuate over a period of years.

To date, there is no completed research into the effect of fire on rainfall – runoff relationships in buttongrass moorland. The peatland streams and fire project presently being run by the Geodiversity Conservation and Management Section of DPIPWE is investigating this issue, but is not expected to report for some years.

To date no recommendations have been made to specifically reduce the impact of management burns on stream hydrology.

Geomorphology

Fire can have a very significant effect on the rates of many geomorphic processes, including soil erosion (covered above), deposition of sediment by overland flow or mass movement, stream erosion and deposition. It can potentially destabilise aeolian features, although these are not known from buttongrass moorlands. It can also influence the rates of rock weathering. There is potential for the features produced after fire to remain visible in the landscape for long periods.

Changes to slopes

As described above, fire can increase rates of soil erosion in a variety of ways, including wind and water erosion, and mass movements. This erosion will affect both the organic and mineral components of the soil. These processes can produce depositional features such as microterraces (where sediments are deposited behind obstructions), and sediment drapes over lower slopes and marginal areas of valley floors. The soil depth in these depositional areas may increase. However, such increases must be associated with areas of soil loss upslope. Also, the character of this deposited material is likely to differ from soils developed in situ.

Where fire burns part of the peat surface, there is potential to create an undulating surface that could be long lasting. Burnt pockets could form depressions that trap water to form pools. These potentially survive a long time, and will have an influence on overland flow, infiltration rates, and interact with the flora and fauna of the area.

At present, there are no published results of investigations into the magnitude of post-fire sediment movement within or loss from moorland landscapes, or the time over which increased sediment movements or the features created persist. Some data exists showing that mineral soils are more erodible than organic soils (di Folco, unpublished data). Assessments of the frequency and temporal persistence of post-fire depositional features are also lacking.

See the section on soil loss due to mechanical erosion for suggested prescriptions that may reduce erosion.

Changes to streams

Intense catchment-scale fire has the potential to cause a complex set of responses in waterways. This can include both erosion and deposition, which may occur at different locations, or at the same location at different times. These changes affect not only the river channel, but also the floodplain features and hydrology. The effects can also extend beyond the area directly affected by the fire, as the altered hydrology and sediment transport rates may persist downstream until the catchment area includes a significant unburnt area, or the geomorphic controls on the waterway change significantly.

Fire can increase rates of stream erosion (Shakesby and Doerr 2006). This occurs because stream power typically increases after a fire, due to a combination of increased flood depth and reduced bank and floodplain roughness where riparian vegetation has been burnt. At the same time, the death of roots binding the stream bank and bed increases the susceptibility of these sediments to erosion. The net result can be significant bed incision and channel enlargement. An example of this was documented at Surprise Creek in the Vale of Rasselas (Jerie 2005) although a firm link between the erosion and a specific fire has not been made. Observational data also exists for significant stream erosion 18 months after fire at Twelvetrees Range. Increased rates of sediment transport post-fire have been observed at Gelignite Creek in ongoing research by DPIPWE (unpublished data). Such stream erosion can cause major changes to channel form, including altered sinuosity, number of channels, channel cross section size and shape, and connections with floodplains. In some areas, gully erosion and erosion along soil pipes will cause the channel network to extend upslope.

Because fire can lead to increased rates of erosion both on slopes and in channels, it can produce significant quantities of sediment. This can lead to large quantities of sediment entering streams and rivers, which can cause changes to the channel and floodplain character. When sediment inputs are high, deposition on the bed reduces channel depth, which increases erosive pressure on banks. Channels that are choked with sediment may become wide and shallow, with considerable lateral instability. Fire related sediment may also change the character of the stream bed in terms of grain size and bed features.

Such changes have been described in a range of environments around the world, but with a focus on forested areas (Shakesby and Doerr 2006). As yet there is a lack of research into the effect of fire on moorland streams and rivers in Tasmania. The peatland streams and fire project presently being run by the Geodiversity Conservation and Management Section may answer some of these questions in the context of a very small buttongrass catchment, but is not expected to report for some years.

No recommendations have been made to reduce the impact of management burns on stream geomorphology.

Changes to rock weathering

Heating and cooling caused by fire can cause significant mechanical weathering of exposed rock (Shakesby and Doerr 2006). This impact is unlikely to be large, but could potentially have implications to features with specific geoconservation value.

Fire induced weathering takes the form of spalling of flakes of rock from exposed surfaces, and fracturing of smaller boulders. Denudation rates caused by exposure to intense fires can be very high in the context of estimated rates of landscape, although the effect depends on the intensity of the fire, and also on the lithology, boulder size and water content of exposed rocks (Shakesby and Doerr 2006). For example, significant spalling has been reported from granite, sandstone, limestone, while other lithology including gneiss and mica schist are apparently less effected (Shakesby and Doerr 2006).

The impact of fire on rock weathering rates in southwest Tasmania has not been reported. It is probable that rates would vary widely given the range of rock types present. Also, the research summarised above focuses on the effects of high intensity wildfires. It is not clear how likely it is that such weathering may occur during the low to moderate intensity prescribed management fires.

No recommendations have been made to reduce the impact of management burns on rock weathering rates.

A summary of recommendations for prescribed buttongrass moorland fires

- Only burn when the Soil Dryness Index is less than 10 (Marsden-Smedley *et al.* 1999).[1]
- Use field based assessments of soil moisture, as Soil Dryness Index does not work well for peat soils (Marsden-Smedley 1993; Bridle *et al.* 2003).
- Avoid burning areas where there is evidence for past soil loss, such as extensive gravel or bedrock outcrops, soil pedestals and truncated peat profiles (Pemberton and Bridle 2003).
- Avoid burning areas where peat soils are likely to dry out, such as on slopes over 15°, or where the peat is underlain by a free draining sandy or gravely substrate (Pemberton and Bridle 2003).
- Avoid burning where there is dead vegetation and dry peat edges that can provide access for the fire into the soil (Pemberton and Bridle 2003).
- After a fire, use aerial assessments with onground follow up to identify areas of smouldering peat, and take appropriate steps to extinguish them (Pemberton and Bridle 2003).
- Avoid burns on slopes over 15°, as these will be prone to erosion (Pemberton and Bridle 2003).
- Aim to leave a litter layer on the ground after the fire, as this will reduce erosion, and drying of the soil surface (Pemberton and Bridle 2003).
- Conduct management burns in autumn so that bare ground has the chance to develop some vegetation cover before summer. The bare peat surfaces will heat up significantly in summer (Pemberton and Bridle 2003).
- Adopt a burning interval of between 20 and 30 years (Bridle *et al.* 2003). This may allow peat accumulation to occur between fires.

Conclusions

It is clear that fire can impact the soils and landforms of buttongrass moorland, as well as the vegetation. Fire management debates occur between the extreme strategy of a) very regular management burning to minimise risk of intense wildfires, or b) little management burning with a higher risk of intense summer wildfires. It should be understood that both strategies will risk permanent changes to the landscape. Although

[1] Note Marsden-Smedley (2009) recommends that in situations where there are mineral earth boundaries such as roads and tracks or water courses or lakes, prescribed burning may be conducted provided that the SDI is less than 20. In such circumstances he advises that the fire will be able to spread into areas of scrub. Such prescriptions would generally only be applied within asset protection zones or fuel management zone.

changes caused by the former strategy are likely to be incremental, they can potentially be just as fundamental and permanent as the catastrophic changes risked by the latter strategy. The most benign strategy is likely to be a site specific compromise position based on values and risks at both the landscape and local scale.

Fire management of buttongrass moorland sometimes focuses on minimising risks to biological or built assets in areas surrounding the moorland. Hopefully, this overview of potential impacts of fire makes it clear that fire can also impact the landscape within the moorland. The values and sensitivities of the non-biological component of moorland areas should also be taken into account when planning fire management.

There are many significant gaps in our knowledge that must be filled before we will understand all the compromises we are making when deciding on a fire regime. Some of these questions are being addressed in the 'Peatland streams and fire' project, run by DPIPWE at Gelignite Creek and Condominium Creek on Scotts Peak Road. Other questions include, but are not limited to, the following:

- What are the present and past rates of organic soil formation across a range of buttongrass moorland environments?
- By what mechanisms does new organic soil material form?
- What is the relationship between soil character, fire intensity and soil combustion?
- What are the relative rates of soil loss (caused by mechanical erosion or decomposition) in burnt and unburnt areas, and how does this relate to fire intensity?
- How does landscape position (ie steep slopes versus valley bottoms) influence susceptibility to soil loss during and following fire?
- How does fire impact on hydrology at the scale of soil profiles, slopes and entire catchments?
- To what extent do the geomorphic features associated with moorland areas occur because of fire, and to what extent might they be altered by fire and by post-fire erosion?
- Which features of soil and landscape should be a priority for protection when considering fire regimes? Note that this would include features that require fire, as well as those that are damaged by fire.
- What is the relaxation time required for the characteristics of moorland post-fire changes to return to pre-burn conditions?

Acknowledgments

Thanks to Kerry Bridle and Maj-Britt di Folco of the University of Tasmania, and Jayne Balmer and Ian Houshold of DPIPWE, for comments on drafts of this paper.

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A review of vegetation responses to fire in buttongrass moorland

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Introduction

This review explores the existing literature, theories and available data relating to Tasmanian buttongrass moorland vegetation and fire. This information is used to recommend the most appropriate fire regimes (frequency, intensity and seasonality) within this ecosystem for vegetation conservation.

Effects of fire on buttongrass moorland soil and vegetation

Overview

State-wide and regional studies of buttongrass moorland and heath have concluded that soil drainage and fertility are the most fundamental influences on the floristic composition and structure within these treeless ecosystems (Kirkpatrick 1977, Jarman *et al.* 1988ab, Kirkpatrick and Harris 1999). Nevertheless there are changes in floristic composition and structure with TSF (e.g. Brown *et al.* 2002, Balmer and Storey unpublished data). Observed fire impacts on vegetation and the patterns of recovery with TSF are described below.

Influence of fire intensity and behaviour on soils and plant species survival

Cool fires, may not kill all above ground plant biomass. In particular ground hugging herbs such as *Actinotus*, *Lycopodiella*, bryophytes and lichens may survive the fire. Small patches of taller unburnt vegetation may also remain. Above ground survival of plants stems may occur due to a variety of influencing factors. Sparse vegetation structure in which there are large areas of exposed gravel or sandy/silt pans or pools and/or cool low intensity burning conditions may lead to a patchy fire in which islands of vegetation may escape burning. Likewise particularly dense and wet patches of vegetation may not burn in these conditions either. Wind driven fires and fires travelling up-slopes are hotter and burn the vegetation more completely than cooler fires, but they may still jump or miss small areas in drainage lines or topographic depressions. Hot summer wildfires typically leave no surviving above ground plant stems. In particularly intense summer wildfires the woody seed capsules along with their seed may be consumed by the fire (personal observations). The loss of vegetation on slopes followed by winter rains can result in severe erosion particularly after wildfire (Pemberton 1988).

Following cool fires, there may be a large amount of dead plant material left unburnt, particularly in areas where the vegetation is dense and wet. This dead material collapses to form a dense ground cover of thatch. Thatch may function in ways that affect the accumulation or decomposition of organic matter in the soils (Bridle *et al.* 2003, Jerry 2010). But it may also affect the post-fire germination rates.

The thatch is important in retaining soil moisture and reducing heating during the summer months following fire when vegetation cover is sparse. Soils without thatch will be more vulnerable to erosion and depletion of organic content. Unfortunately the thatch also provides a fuel source which will carry wildfire within the first year or two following fire. The decomposition of the fire-generated thatch during the first two years is likely to render it a negligible fuel source after two years (JB personal observations).

In conclusion prescribed fires for ecological purposes will be less likely to impact on soils and community composition if fires are cool enough to retain areas of thatch and unburnt vegetation islands. Steeply sloping areas may be more vulnerable to erosion and loss of organic content than flat areas. Nevertheless some variability in fire intensity across the landscape will promote a range of opportunities for different species and promote maximum habitat diversity in the long term— potentially reducing future fire intensity in the event of a summer wild fire.

Post-fire vascular plant regeneration strategies

About 200 plant species typically occur in Tasmanian buttongrass moorlands (Jarman *et al.* 1988a, Pemberton *et al.* 2005) of which 30% are endemic to Tasmania. Data (from Tasmania and other states) is available on the regeneration strategies of 69% of these species (Gill and Bradstock 1992, Balmer and Storey unpublished data). Of those for which information is available, 90% have been observed to regenerate vegetatively (at least sometimes) following low intensity wildfire from underground rhizomes/root stocks or basal stems/lignotubers. Seedlings have rarely been observed after cool fires for half of these species. The large reliance on vegetative regeneration means that this vegetation is resistant to floristic change following low intensity fires.

Of the species for which regeneration strategies are known, 40% commonly regenerate from seed but are not obligate seed regenerators (e.g. *Bauera rubioides*) and 10% are obligate seed regenerators (e.g. *Almaleea subumbellata*, *Comesperma retusum, Epacris obtusifolia, Euphrasia gibbsiae, Leptospermum glaucescens, Melaleuca squamea* and *Sprengelia incarnata)* (Gellie 1980, Balmer and Storey unpublished data). These species have seed that typically survives fire in aerially stored woody capsules or else in the soil seed bank. Release of seed and/or germination may be triggered by several factors including heat, smoke, nutrient release, increased light availability at the soil surface and/or death of parent plants during or following fire. Woody capsules generally open within three days of the fire releasing huge quantities of seed (Gellie 1980).

To date, germination trials have been undertaken on very few buttongrass moorland species (Tasmanian Seed Conservation Centre germination data base, 2011). However there are many Australian species from a range of genera for which heat and/or smoke break dormancy or increase the rate and speed of germination. Buttongrass moorland genera that include species that respond positively to smoke include *Actinotus, Allocasuarina, Banksia, Boronia, Caesia, Comesperma, Drosera, Epacris, Exocarpos, Hakea, Hibbertia, Hydrocotyle, Laxmannia, Leptospermum, Leucopogon, Melaleuca, Mitrasacme, Patersonia, Stylidium, Tetraria* and *Xanthosia* (Grayson Australia, undated). Buttongrass moorland species known to germinate in response to smoke include *Epacris lanuginosa* and *E. stuartii.*

The results of a small study of untreated soil from moorland vegetation at different times since fire (~1 month, 4 years and 14 years) showed that twice as many seedlings germinated from recently burnt soil compared with the other two soils (Balmer and Storey unpublished data). This supports the theory that fire/smoke is a major trigger for germination and that much seed remains dormant in the soil following manual disturbance and increased light availability. Nevertheless substantial germination of seed did still occur in the older soils in the absence of a fire cue, indicating that fire is not essential to trigger all species/seed germination. Species without aerially stored seed such as *Sprengelia incarnata* and *Epacris* species showed a strong germination response only from the recently burnt soils. *Melaleuca squamea* seed (stored in nuts) germinated only from the oldest soils revealing that seed release from woody capsules of this species occurs even in the absence of wildfire. The absence of seedlings of this species from younger soil (4 years old) was presumably because the plants at this site had not reached sexual maturity. One seedling did germinate from recently burnt vegetation but the relative absence of germinants was likely to be because most of the seed released following the fire had already germinated (Balmer and Storey unpublished data).

The patterns of plant regeneration at sites in which large amounts of thatch is left may differ from areas where the ground is left bare following fire. A significantly lower density of seedlings were observed where thatch cover was high (Navarre Plains, Balmer and Storey unpublished data). Vegetative regeneration of herbs and shrubs was greater in these areas.

High intensity fires may therefore result in a shift in floristic assemblage since there will be an increased potential for soil-stored seed germination and more bare ground available into which animal and wind born seed plants may colonize. However if fire is intense enough, or the soil dry enough to burn, then the loss of soil through combustion will result in the loss of the seed bank (Brown *et al.* 2002). It would also result in the loss of the soil-nutrient capital, important also for seed germination and growth (Bowman *et al.* 1986).

Species relying on regeneration from soil or aerially-stored seed, although usually able to reach sexual maturity within five years of germination, are more vulnerable to elimination or population reductions if fire intervals are less than five years or are repeatedly less than once in ten years (Bradstock and Myerscough 1988).

The dynamics and longevity of soil-stored seed banks is poorly known. However the post-fire community typically includes several short-lived species, rare or absent in the vegetation prior to the fire (Balmer and Storey unpublished data). These species are likely to occur because of the presence of their seed in the soil seed bank. Such taxa include members of the genera *Comesperma, Deyeuxia, Drosera, Ehrharta, Euphrasia, Gonocarpus, Schoenus* and *Viola*. Several of these genera occur in the post-fire community of other vegetation types. For example *Viola hederacea* is typical of recently burnt wet forest communities where fire intervals of longer than 60 years are common. This suggests that the seed can remain viable for periods at least as long as this, although some decline in viability is likely to occur over time (Auld *et al.* 2000).

In conclusion most species are likely to be resilient to regular cool burning. However to maintain populations of obligate seeders within the vegetation, planned fire intervals should rarely be less than ten years and never less than five years. Fires burning soils should be avoided because these will burn soil-stored seed and reduce the soil nutrient capital.

Plant dispersal patterns

Few moorland plants are thought to be able to disperse over long distances (i.e. have wind buoyant or animal dispersed seed). Although information on seed dispersal is only known for about 50% of buttongrass moorland plant species 95% of these are considered to have poor dispersal capacity. Wind dispersed species include daisies in genera such as *Erigeron, Olearia* and *Ozothamnus,* while animal dispersed species include fleshy fruited genera such as *Exocarpos* and *Coprosma* and barbed/sticky seeds such as *Uncinia* and *Acaena*. Increased bare ground following intense fire provides a suitable opening for these species to recolonise. However the potential for this to occur relies on the presence of populations in adjoining areas that remain unburnt.

In order to promote opportunities for distance dispersal, planned fires should be relatively small (under 20 ha) or aim to retain islands of unburnt vegetation. Areas planned for burning should ideally have nearby vegetation (or retain islands) that have not been burnt for fifteen years or (less ideally) at least five (fertile sites) or ten years (low fertility sites).

The effect of time since fire (TSF) on vegetation

TSF following cool, low-intensity management-burns of buttongrass moorland exerts only a minor influence on the floristic assemblage of the vegetation in comparison to the influence exerted by disease, drainage and fertility (Balmer and Storey unpublished data). Monitoring at several locations in south-west Tasmania (including Birchs' Inlet, Bathurst Harbour, Sandfly Creek, McPartlans Pass, Airstrip Road) and central Tasmania (Navarre Plains) has shown that the recovery of the floristic community to an assemblage that approaches that of the pre-burn community occurs within the first five to ten years of burning (Balmer and Storey unpublished data). The speed of recovery appears to be most affected by site fertility. The most rapid recovery occurred in the moderately fertile communities at Navarre Plains whereas large areas of bare ground were still present seven years after fire at the low fertility site at

Airstrip Road in southwest Tasmania. At low fertility sites the height and density of the vegetation is particularly slow to recover and at Airstrip Road had not reached pre-burn levels even ten years after fire (M. Driessen personal communication).

Within six weeks of the fire the majority of species in the pre-burn vegetation begin to resprout, shooting new leaves and stems from surviving below ground or surface rootstock, rhizomes and basal stems.

In spring and summer seedlings, bryophytes and lichens begin to colonise bare ground. Some of these seedlings are species which were much rarer or not present at the site immediately pre-fire, which germinate from the soil-stored seed bank. Most of these species are herbs or grasses. Many resprouting species also germinate as seedlings. Some species able to resprout at some sites/fires rely principally upon germination from seed at other sites/times (e.g. *Bauera rubioides* relied on regeneration from seed at Airstrip road but resprouted at other sites).

Germination of seedlings continued at a reduced frequency with time. Ground disturbance such as digging and trampling appeared to result in the stimulation of seedling germination in unburnt areas but on a reduced scale compared with burning. The success of seedlings in more mature vegetation has not been studied.

Other results observed in relation to community change with time were that:

- Species richness for both vascular and non-vascular plants was inversely correlated with cover of *Gymnoschoenus sphaerocephalus* over time (DPIPWE data, Jones 2007).
- Species richness of vascular plants was highest in the first three to five years following fire (DPIPWE data).
- Bryophyte species, herbaceous species and grasses peaked between 1 and 3 years following fire and all declined in cover and frequency in response to the expansion of buttongrass cover (DPIPWE data, Jones 2007).
- Shrubs were slower to recover their height and cover compared with sedges, reaching pre-burn covers within 6 years of fire (DPIPWE data).
- Increases in species richness following fire were less marked at lower fertility sites and vascular vegetation recovery took much longer than at higher fertility sites (DPIPWE data).
- Bryophytes and lichen species had a greater diversity and abundance at the low fertility sites following fire and showed more marked changes in species richness with time (Jones 2007).

Chronosequence studies of buttongrass moorland suggest that buttongrass moorland communities may be maintained in the absence of fire for 70 years or longer at low fertility sites (Driessen unpublished data, Balmer and Storey unpublished data. A site at White Spur Road has three ages of vegetation (70, 110 and 130 years). The vegetation in all three age classes includes buttongrass moorland hummocks and other buttongrass moorland species. However the height and density of the shrubs/trees increase with age. The 70 year old vegetation fitted the definition of layered blanket moor (sensu Jarman *et al.* 1988a) but the 110 and 130 year old vegetation was structurally scrub and forest respectively.

This and other data from chronosequence studies suggest that apart from early coloniser species, which are most common in the first five to ten years post-fire, that many species in moorland communities are retained as it ages and changes structurally from moorland to scrub and forest. Naturally there is a change in the importance of many of these species in terms of both frequency, height and cover with graminoids and herbs becoming less important while shrubs and trees increase in importance with time. Change with time is likely to be more rapid in more fertile habitats.

From the limited evidence available burning buttongrass moorlands to maintain the regional species diversity does not appear to be a particular priority. Nevertheless a varied fire regime should ensure opportunities for the greatest number of different species in the region.

Effect of fire frequency on vegetation

Almost no work has been undertaken on the effects of fire frequency within buttongrass moorland on vegetation or soil characteristics. Such work would require a better knowledge of past fire history or longer monitoring periods than we have so far had at our disposal. A mainland study concluded wet heath communities subject to different fire frequencies over two decades were not significantly different (Myerscough and Clarke 2007). Nevertheless fire frequency studies across vegetation types indicate strong support for Jackson (1968) model of ecological drift, and show that buttongrass moorlands are associated with higher fire frequencies than scrub and forest vegetation (Brown and Podger 1982a). Similarly over long periods of time, differences in fire frequency are likely to result in differences within buttongrass moorland vegetation as well (Kirkpatrick 1977, Brown *et al.* 2002).

Increased fire frequency will result in reduced intervals between fires and so it follows that the vegetation will be younger on average and have a lower average biomass and height. Less biomass will be available from which a post-fire thatch layer can be derived and hence impacts on soils are likely to be greater, with high potential losses of organic matter or at least slower organic accumulation rates. Shorter return times between fires might expect to reduce the relative importance of obligate seeders and shrubs compared with non-woody species and species regenerating vegetatively.

In general it seems likely that short term changes in fire frequency will have little impact on buttongrass communities and it is only where consistent change in fire frequency is maintained over a long period of time (a century or more) that an impact would be discernable. Therefore it is recommended that to maintain the greatest range of species in the community that frequency be varied across the landscape. Nevertheless it is also recommended that the majority of the landscape be burnt at a relatively low frequency given the potential impacts on soils of high fire frequencies.

Fire frequency and disease interaction

In comparison with fire, the introduction of plant disease (e.g. *Phytophthora cinnamomi)* has a much more profound impact on buttongrass moorland communities since it may severely reduce and locally eliminate populations of several plant taxa including *Agastachys*, Baeckea, *Banksia*, *Blandfordia, Hibbertia procumbens, Isophysis, Euphrasia, Exocarpos*, *Epacris*, *Sprengelia,* (Podger *et al.* 1990, Brown *et al.* 2002, Rudman and Balmer 2007). Among the species impacted by *Phytophthora cinnamomi* are endemics with distributions almost entirely restricted to buttongrass moorland (e.g. *Epacris corymbiflora*).

Increasing fire frequency and/or fire intensity is likely to cause an increase in average soil temperatures and so is likely to increase the vulnerability of buttongrass moorland to impacts from *Phytophthora cinnamomi*. It is therefore recommended that to avoid increased impacts from *Phytophthora cinnamomi,* that vegetation should be only infrequently burnt, with low intensity fire that promotes the generation of thatch.

Effect of fire seasonality on vegetation

The affect of varying season of prescribed burn on buttongrass moorland vegetation has not been the focus of any studies. However it is apparent from observational and descriptive accounts that the impacts of wildfires burning in dry, hot, windy conditions are far greater in terms of total biomass and soil losses, than would ever occur in cool wet conditions. Biodiversity recovery time following fire is likely to be faster where burning conditions are cool and wind speeds low and soil moisture high. Such conditions are most prevalent in autumn and winter through to early spring.

The affect of fire on special moorland values

Balmer *et al.* 2004 describe the World Heritage and other significant conservation values that have been attributed to buttongrass moorland ecosystems and their component species and communities. All prescribed burning needs to take into account the nature conservation values of the target areas. A few examples of species and communities with particular fire requirements or vulnerability to fire are described below.

A species of particular significance is the endemic monotypic genus of moss *Ambuchanania leucobryoides*, which is restricted to a few acid sand pans in lowland areas (*Johnston et al.* 2008). The presence of this species in sandy outwash pans suggests that fire and local erosion events are needed to maintain its habitat. Likewise alkaline pans that occur within buttongrass moorland regions may require fire to remove organic soil horizons in order to expose and retain the alkaline substrates and limestone gravels which provide habitat for this specialist endemic flora (Brown *et al.* 1982).

The relationship of fire to the formation and maintenance of the lowland peat mound formations remains unclear, although they occur in regions that have been subjected to a long history of regular frequent fires, suggesting that they may be relatively resilient to impacts from this regime. Fire regimes that result in intense summer fires would be likely to cause peat fires in these mounds and so are to be avoided.

Whinam (2007) has highlighted the impact of even cool prescribed burning on *Sphagnum* peatlands that occur in small to large patches within some buttongrass moorland areas, especially the central highlands. To maintain this community within the buttongrass moorland mosaic, fires should be restricted to times when peats are fully saturated. Even then a specialist lighting and protection plan is needed to ensure that the *Sphagnum* peatland areas are not burnt.

To prevent degradation of moorland communities in general, prescribed burning needs to take into account soil depth and slope. Burning areas of skeletal soil and steep slopes should be infrequent and restricted to times when soils are saturated.

Many fire sensitive conservation values are represented in communities that adjoin buttongrass moorlands. Such values are at risk from escaping buttongrass moorland fires only when they are dry enough to burn. The results from King's (2004) computer simulated fire modelling suggested that significant areas of rainforest are only burnt in situations where buttongrass moorland fires have become large and high intensity when they penetrate the rainforest boundary. Conditions for such landscape scale-fires are only typical in summer and early autumn. Lowering fuel loads in buttongrass moorlands in areas with fire sensitive assets will reduce the likely-hood of fire-sensitive communities burning but it will not eliminate the risk completely (King 2004).

Recommendations

Management of asset protection areas

Asset protection management zones (areas in which the principle objective of management is to maintain low fuel loads) be applied only to areas where it can be demonstrated that lowering fuel loads will reduce the risk of landscape-scale fires impacting on fire-sensitive vegetation communities, loss of life or some other significant fire-sensitive asset. The existence of natural values that may be at risk from fire management practices be considered and taken into account when planning asset management zone boundaries and fire regimes.

Asset protection zones be burnt in strips or patches such that the fuel loads in the overall zone area is low enough to reduce the rate of spread and intensity of fire across the zone in summer, but which also enables burning to occur at intervals of no less than six (high fertility area) to ten years (low fertility area) for any component part.

Patches burnt in asset protection zones be kept relatively small or narrow and where possible be chosen each year such that there is an adjoining patch that hasn't been burnt for more than four years and preferably six years or more. This may increase the speed of community recovery (particularly the recolonisation and utilisation of the area by animals).

Management of remaining moorland areas in the conservation reserve system

Fire interval

A minimum fire interval of seven (high fertility sites) to 15 years (low fertility sites);

Aim to ensure that fire intervals are varied at each site and across the landscape while restricting the opportunity for a short fire interval to be followed by a second short-fire interval.

A maximum inter-fire period between 30 (high fertility site) and 60 years (low fertility site) where it is desirable to maintain the vegetation as buttongrass;

Seasonality

Fires should be restricted to times when soil moisture is high and be undertaken on days when wind speed and temperature is low and humidity high.

Fire intensity

The planned fire intensity for most areas of prescribed ecological burning should be low so as to promote the generation of thatch to protect post-fire soils. Nevertheless managers should aim to develop a lighting strategy that generates a patchy fire with some hot-spots and some unburnt areas so that there will be opportunities for a greater range of species responses.

Patch size and spatial arrangement

Planned burn areas should aim to be relatively small (less than 20 ha) with a large edge to area ratio or if larger than include substantial unburnt islands to enable recolonisation (fauna and flora) from unburnt patches.

Planned burning should aim to avoid areas of steep slopes, skeletal soils and fire sensitive assets such *Sphagnum* peatland where possible. Where such values occur within the planned burn area the impact on these should be reduced through lighting strategies and protection measures.

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A review of fauna responses to fire in buttongrass moorland

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There has been limited research conducted on the response of fauna to fire and fire frequencies in buttongrass moorlands. Of the research that has been undertaken most has been limited in scope, unpublished and or not well designed in terms of controls and replication. In recent years a number of better designed studies have been undertaken but most of these have yet to be completed and published. Studies on the responses of fauna to fire in buttongrass moorlands and their implications for management are summarised below.

Birds

In Tasmania, buttongrass moorland is the primary habitat for three bird species; the striated field-wren, the ground parrot and the southern emu-wren. Many other bird species use the habitat for feeding (Brown *et al.* 1993; Chaudhry 2010). Although no bird species is restricted to buttongrass moorland, the orange-bellied parrot is dependent on buttongrass moorland for feeding during its breeding season.

Observations on orange-bellied parrots suggest that optimal feeding areas occur in buttongrass moorlands between three and twelve years of age and that habitat >20 years of age is unsuitable for the birds (Brown and Wilson 1984). However, no experimental data were supplied to support these conclusions. Holdsworth (2006) observed an increase in egg fertility a year after a major wildlife and attributed this to a flush in growth of food plants. Eggs and chicks, which live in *Eucalyptus* tree hollows, are vulnerable to wildfire (OBP Recovery Team 2006). The national recovery plan for the orange-bellied parrot recommends patch burning around known and potential orange-bellied parrot breeding sites (OBP Recovery Team 2006). The Melaleuca-South West Cape Fire Management Plan (PWS 1997) recommends burning eight patches in the Melaleuca area for orange-bellied parrot habitat management. Patches range in size from 12–178 ha (total 709 ha) and are to be burnt on a 10–12 year rotation. The national recovery plan recommends further research into the fire ecology of the orange-bellied parrot (OBP Recovery Team 2006).

In a study investigating the distribution and conservation status of the ground parrot in Tasmania, Bryant (1991) found that the species occurred at sites ranging in age since last fire from 1–90 years. Peak densities occurred 4–7 years after a fire, although moderate bird densities persisted in buttongrass moorland 35 years post-fire. Gellie (1980) also reported that ground parrots are often found in areas unburnt for over 20 years. Bryant (1991) provided tentative management prescriptions for burning for ground parrots, including burning between April and September, no areas to be completely burnt, and burning in a mosaic so that not more than 25% of the habitat is burnt on a 10 year rotation.

Gellie (1980) stated that southern emu-wrens and striated fieldwrens require dense vegetation for cover and nest material, and both species may take from 5–7 years to return to an area to breed after a fire, unless suitable pockets of unburnt vegetation are left as breeding areas.

All three bird species that spend their entire life-cycle in buttongrass moorland and the orange-bellied parrot, which depends on this habitat, breed in spring to early summer. Spring fires are likely to destroy many nests and kill young birds, while autumn burns are preferable as they allow time for young birds to become mobile (Gellie 1980).

In the most comprehensive study to date of buttongrass moorland birds, Chaudhry (2010) used a replicated space-for-time design to investigate post-fire responses of resident and non-resident birds at two locations (also see Chaudhry *et al.* 2010). Observed patterns of bird diversity, density, and habitat use across the two chronosequences were complex and revealed high levels of inter-specific and inter-site variation in relation to habitat variables. Overall, mean densities of the resident species at the low productivity location increased across the chronosequence, while at the medium productivity location they peaked 2–8 years post-fire. Mean densities of the non-resident species did not exhibit any consistent trends in relation to fire age. A short-term (1.5 years post-fire) paired before-after-control-fire study was undertaken at the medium productivity location. This study indicated that hazard-reduction burning in moorlands may result in overall reductions in resident avian densities and increases in non-resident densities in the short-term. Chaudhry (2010) discussed the management implications of his results in light of previous studies on birds and previous fire recommendations for fauna. His study highlighted the importance of moorland riparian vegetation for birds and the need to protect it from fire during planned burning operations. Chaudhry (2010) also noted that, planned burns should occur between March and June to avoid burning during the breeding season of birds, which is more conservative than previous recommendations for ecological burning (March–September).

Small mammals

Three species of mammal, the swamp antechinus, the broad-toothed mouse and the swamp rat, spend their entire life-cycle in buttongrass moorland. Other mammal species feed in buttongrass moorlands and typically shelter in adjacent habitats (Driessen 2006, 2007). No mammal species is restricted to buttongrass moorlands.

Gellie (1980) reviewed the limited data on the ecology of small mammals in buttongrass moorland in relation to fire and concluded that swamp rats, broad-toothed mice and swamp antechinus prefer buttongrass moorland with dense cover, and that all three species may require 10–15 years after a fire for the vegetation to recover sufficiently for recolonisation. Gellie (1980) stressed the importance of leaving pockets of unburnt vegetation to allow recolonisation of burnt patches to occur. All three species have a spring breeding period, and Gellie (1980) recommended autumn as the preferred time for burning.

Arkell (1995) surveyed small mammals at three locations comprising a total 15 sites, ranging in fire-age from 1–43 years. He found that species diversity, based on three species, peaked between 5 and 10 years after a fire. However the study was limited due to low capture rates particularly for broad-toothed mice and confounding differences between sites.

Driessen (1999) reported preliminary results on small mammal succession following low intensity hazard reduction burns in montane buttongrass moorland using a before-after-control-impact design with limited replication (two treatment sites and one control). Populations of broad-toothed mice, swamp rats and swamp antechinus were not recorded from treatment sites immediately after they were burnt. Recovery of the all three mammal species to pre-burn capture rates took between four and five years and appeared to be related to vegetation density returning to pre-burn levels. The broad-toothed mouse, a species previously thought to require long (>15 years) unburnt habitat, recovered to pre-burn levels three years after the hazard reduction burns when vegetation densities were 75% of pre-burn levels. The overall pattern of response to the hazard reduction burns was similar for the two treatment sites investigated even though one was burnt in spring and the other in autumn. The small mammal study sites were 20 years old at the time of burning. Therefore, a recovery of small mammals to pre-burn (i.e. 20 year) levels 4–5 years after a burn suggests that there may be little change in small mammals in buttongrass moorland between ages 5–20 years.

Longer intervals between burns may be required in lowland buttongrass moorland on nutrient-poor soils as vegetation recovery after fire is much slower than in montane areas on more productive soils (M. Driessen unpublished data). Retention of unburnt patches in and around burn areas is also likely to enhance survival and speed the recovery of small mammals, but further research is required on the size of viable patches and optimal location of the patches. The cumulative impact of repeated burns on the recovery of small mammals also requires investigation.

Reptiles, amphibians and freshwater fish

Five reptile species, five frog species and one species of freshwater fish spend their entire life-cycle in buttongrass moorlands (Driessen 2006, 2007). With the possible exceptions of the Tasmanian tree frog and swamp galaxias no species in these taxa are restricted to buttongrass moorland. There has been no research into response of species within these taxa to fire.

Invertebrates

Although buttongrass moorland invertebrates have not been well documented, most species will spend their entire life-cycle in this habitat. The number of species that are restricted to this habitat is not known. Burrowing crayfish have been recognised as a keystone species (Richardson and Doran 2007). The rare Hickman's Pygmy Mountain Shrimp is restricted to this habitat (Driessen *et al.* 2006). Information on buttongrass moorland invertebrates is available in Brown *et al.* (1993), Greenslade and Smith (1999), Driessen (2006) and Green (2009).

Greenslade and Driessen (1999) investigated the relationship between the age of buttongrass moorland and the abundance and diversity of invertebrates using a space-for-time approach. Using sweep nets, a total of 27 sites, ranging in age from 1 month to 64 years since the last fire, were surveyed at three different locations with different levels of soil productivity. The study was limited by inadequate distribution and replication of age classes at each location. In general, both number of captures and morphospecies richness was lowest in younger regrowth sites (1–5 years). Mites, spiders, springtails, beetles, flies and moths were the taxa most influenced by site age.

Driessen and Greenslade (2004) used a paired design (4 sites) to compare Collembola communities between young regrowth (< 12 years) and old regrowth (>24 years) in low and medium productivity moorlands. For most taxa there were no differences in numbers caught between young and old regrowth. Several taxa were caught in less numbers in young regrowth sites compared with old regrowth sites but only in low productivity moorlands.

In 1999, a large study commenced investigating the effects of fire on moorland invertebrates using a replicated before-after-control-impact design in low productivity and medium productivity locations (three treatments, three controls/location, Driessen unpublished data). The vegetation of these sites was also surveyed (Storey and Balmer 2010). Invertebrates were sampled by sweep nets and pitfall traps. To compliment the BACI study and to obtain insights into long-term invertebrate succession, a replicated space-for-time study was undertaken in 2004. The space-for-time study was also undertaken in low productivity moorlands (19 sites) and medium productivity moorlands (25 sites). Many of these sites were established in conjunction with the study on birds by Chaudhry (2010). The results of the invertebrate studies are still being analysed but initial results suggest:

- diversity and number of captures of invertebrates is reduced immediately following fire;
- recovery of the invertebrate community to pre-burn composition is slower in low productivity moorlands (up to 13 years) than in medium productivity moorlands (<6 years);
- after the initial post-fire decline, some taxa, in comparison with pre-fire captures, increase, some remain reduced and others return to the same level;
- the number of captures of several herbivorous taxa appear to increase in the years following burning (e.g. some crickets, flies, springtails and beetles), presumably responding to 'green pick'. Some ground spiders also appear to increase;

- taxa such as those dependent on the shrub layer (e.g. Thomisidae spiders) decline after the burn and then recover to pre-fire levels as the vegetation recovers;
- taxa that require decomposing vegetation have not recovered even though the vegetation has return to pre-burn floristic composition and density levels (e.g. amphipods, isopods, some flies); and
- no species were found to be lost in the long-term following fire although this is difficult to determine for rarer taxa; it is possible some taxa may already have been lost from these sites due to previous fire history.

Using soil core sampling, Green (2008, 2009) investigated the impact of fire on soil mites using the space-for-time study sites mentioned above. The soil mite community was found to be rich both at family and species level. Mite density and species diversity were significantly higher 30–40 years post-fire compared with younger age classes suggesting mite populations may take a long time to re-establish fire in buttongrass moorland.

Hickman's pygmy mountain shrimp occurs only in pools in buttongrass moorlands in an area of less than 21km^2 in southwest Tasmania (Driessen *et al.* 2006). It is listed as rare on the schedules of the Tasmanian *Threatened Species Protection Act 1995*. Horowitz (1990) expressed concern that hot or excessively frequent firing of buttongrass has the potential to damage the underlying peat and result in a loss of habitat for this species. Preliminary results from a before-after-control-impact study indicate that this species can persist in an area following a low-intensity fire compared with pre-fire surveys. Capture rates recover to pre-fire levels after six years. (Driessen unpublished data). The potential threat to this species from loss of peat from hot fire remains.

Conclusions

Several general statements can be made regarding the effects of fire and fire frequency on fauna in buttongrass moorland.

- A fire in a patch of buttongrass moorland most likely leads to the death of the majority of small mammals. Most adult birds will be able to avoid a fire. Animals that do escape a burn are likely to die, as the surrounding habitat is likely to be fully occupied. The fates of frogs and reptiles are not well known but both have been observed in burnt areas after fire.
- Fire kills the majority of invertebrates present in a patch of buttongrass moorland, with the exception of some of the more mobile (i.e. flighted) species or those that are protected in the soil.
- The larger the fire area and the faster the fire, the more likely that even highly mobile animals will be killed in a fire.
- Fire during the (spring) breeding season for mammals and birds is likely to lead to the death of young animals, and may increase the chance of adults being killed, particularly for ground nesting birds. Although as stated above fires at other times of year may still result in the death of birds unless of course they are migratory. The response of invertebrates to different season of burn is not known.
- Mean densities of resident bird species is lowest during the first few years following fire with recovery, in terms of mean bird density, quicker (<5 yrs) in medium productivity sites than in low productivity sites. At low productivity sites mean bird densities continue to increase as the moorland ages post-fire (to >30 yrs). The limited evidence available suggests that orange-bellied parrots and ground parrots are most abundant in intermediate-aged buttongrass moorland (5–20 years).
- Small mammals in buttongrass moorland on medium productivity soils are less abundant 1–4 years after a fire, but regain pre-fire densities five years after a fire as vegetation recovers. Small mammals in buttongrass moorland on low productivity soils probably take longer (possibly 10–15 years) to regain pre-burn levels of abundance.
- The limited evidence available suggests different invertebrate taxa respond variously to fire. After an initial post-fire decline some taxa increased in abundance, compared with pre-fire levels, some remain reduced and others return to the same level. Some taxa remain reduced in abundance long after vegetation has apparently recovered. Taxa such as amphipods require build up of decaying vegetation and litter. Soil mites appear to take at least 30 years to return to pre-fire levels of diversity and abundance.
- Any fire intensity and/or frequency which burns the peat and leads to loss of the vegetation will also degrade and lead to loss of fauna habitat. This includes very hot burns and very frequent firing.

- If the absence of fire for a very long period (100+ years) leads to the replacement of buttongrass moorland with wet scrub, there is likely to be a shift in the abundance and/or composition of the invertebrate and vertebrate fauna. However, there is little data available on the changes in both vegetation and fauna in very old buttongrass moorland.
- Further research is required on the response of fauna to different fire frequencies.
- Further research is required on what is an appropriate level of mosaic burning.

Given the general lack of information on the interaction between fauna and fire frequency in buttongrass moorland, it seems premature to apply a 'maximising fauna biodiversity' argument to support a particular fire management strategy for south-west Tasmania. However, the following general recommendations have some supporting evidence and appear to be valid for fauna in buttongrass moorlands:

- avoid very hot fires that burn the underlying peat;
- avoid very frequent firing which can degrade the underlying peat;
- ensure unburnt areas are left, particularly riparian area (i.e. burn in a mosaic);
- where possible, avoid burning during the main breeding/nesting period for birds and mammals (i.e. spring).

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Bumbling through buttongrass

Todd Chaudhry

Golden plains under whimsical skies
Hummocks ‘n puddles and big march flies
Lurching leeches and yabbies abound
The Roaring Forties often the only sound
For the cryptic birds and sable snakes
Slink through the sedges and next to the lakes
Wombats amble through the tussock maze
On a bed of peat where it can rain for days
But a spell of sunshine can dry the mire
And a simple spark unleashes the fire
Burning buttongrass and tea-trees too
Enabling the moorland to grow anew
A world in miniature on the grandest of scales
Forever serenaded by the wailing westerly gales

Fire histories from charcoal and palaeoecology in sedge and shrub bogs

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Abstract

Fire leaves traces in the landscape through micro and macro charcoal, evidence for heating and indirectly through changes in the sediment flux from catchments. Changes in charcoal flux and inorganic inputs can be measured at a range of resolutions up to about decadal. However taphonomy— the ways in which charcoal reaches or is preserved in sites— influences the interpretation considerably so that the type of bog or fen surface and its influent streams can be critical. As an example, surface flow is virtually impossible across a moss surface, so water borne charcoal will disappear from the record if a sedge bog is invaded by a mossland. Fires will then be "invisible" even when widespread in a bog surround.

Charcoal (including partly caramelised plant tissue) is often a major component of the organic content of peatlands. This is true for *Gymnoschoenus* mires in the Blue Mountains and indicates frequent fire events and degradation of other organics in sandstone terrain. Little high resolution work has been published on these profiles and many may not be suitable due to the bioturbation of the profile. However the available records show fire increasing from the mid-Holocene.

In high resolution studies in montane south-eastern Australia it is possible to distinguish between pre-European, grazing and post-grazing charcoal inputs. There is an abrupt transition from moderate charcoal influx to very high inputs followed by low or absent charcoal. This tentatively backs up the interpretation of fire scar records which showed fire recurrence intervals in snow gum of 30 years being replaced by recurrence every 4 years after grazing commenced (Zylstra 2006).

History of buttongrass outside Tasmania

Buttongrass is a hummock-forming sedge distributed in mainland Australia from southeastern South Australia, the Grampians and coastal areas in Victoria to northern New South Wales. Buttongrass moorland occurs both in coastal heaths on leached sands and on montane sandstone sites along the coastal scarp. Both habitats are characterised by poor nutrition and recurrent fire.

There are intriguing gaps such as that south of the Shoalhaven in the Budawang and Kybean mountains where good habitat occurs, and in the coastal heaths between Wollongong and Cape Conran in Victoria. While it is never as extensive as it is in western Tasmania, it forms characteristic hummock communities with shrubs, minor graminoids such as *Xyris* and restiads

Structurally buttongrass moorland is analogous to other frequently burnt peatlands such as *Empodisma* bog and moor (Australia and New Zealand) and sod tussock grasslands (New Guinea to the subantarctic islands).

Very little research has been carried out on the history of the buttongrass moors in mainland Australia. However some records from other types of bogs can throw light on the environmental changes experienced by buttongrass mires. In particular advances in studying past fire can assist management of all mire (peat-forming) communities.

Historical approaches

Bogs contain archival information on vegetation and environmental history that can be interpreted with a variety of techniques including:

- radiocarbon and/or optically stimulated luminescence dating
- Pollen and spores
- Charcoal –micro and macro
- Testate amoebae
- Insects
- Plant macrofossils
- Isotopes and chemistryLarge fires may be detected by investigating:
- macro-charcoal and burnt soil horizons
- tree-rings
- microfossils and micro-charcoal

Dendrochronology

Tree species with annual growth rings such as the snow gum, *Eucalyptus pauciflora*, may be used to identify changes in fire frequency by recording the ages of fire scars within the tree rings (Banks 1986). The tree ring study by Banks (1989) provides strong evidence that fire frequency within the Australian Alps region increased dramatically following the commencement of grazing by European settlers in the 1850s. He showed Aborigines had applied fire to the subalpine landscape only infrequently and in strictly targeted locations (Fig. 1) in the 100 to 200 years prior to European settlement of the region.

Inferring fire histories from charcoal

Charcoal is influenced by fire and source vegetation and also reflects the transport paths. Hot fires (over 500 °C) tend to create ash rather than charcoal. Wetland/sedgeland vegetation types such as buttongrass moorland, which have a high proportion of green foliage, tend to produce more charcoal when burnt. Woody vegetation tends to burn to ash. Therefore a greater quantity of charcoal in a soil profile is not necessarily an indicator of more frequent or intense fires.

When investigating cores from soils or bogs dating the samples and interpreting the stratigraphy can also prove problematic. Soil and peat accumulation rates vary over time and, parts of the profile may be lost due to burning or erosion. Fortunately deep peat fires in buttongrass moorland are rare. Only the surface layer of the soil is likely to be burnt and then only in very intense fires. However, animal digging and burrowing may mix the soil profile removing the relationship between soil depth and time. These problems are likely to be prevalent in Tasmanian buttongrass moorland soils where yabby burrows are frequent and extensive. In hollows where peat depth is greater this is less of a problem.

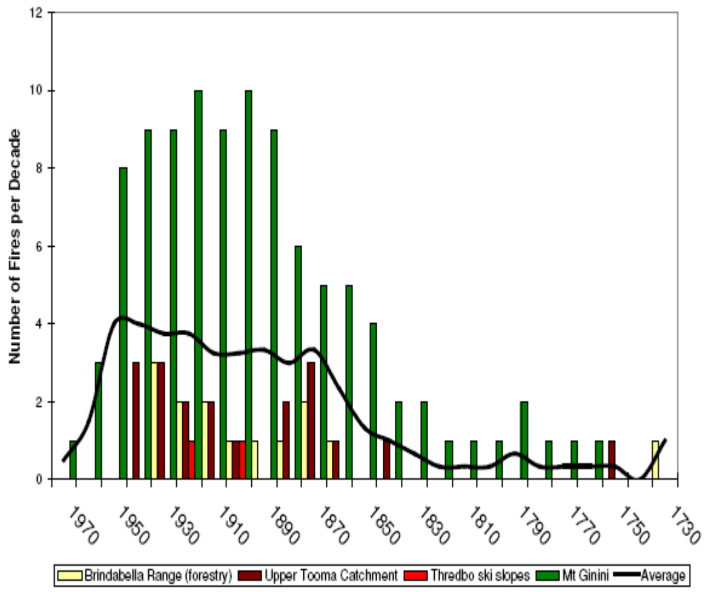

Figure 1: Changing fire regimes within the Australian Alps since 1730 based upon dendro-chronological evidence compiled by Banks (1989). (Figure taken from: Zylstra (2006) Fire history of the Australian Alps. Prehistory to 2003. Australian Alps Liaison Committee.)

A large proportion of the organic content of buttongrass moorland soil may actually be carbonised plant remains. This may explain how the organic content is maintained despite being regularly oxidized. Charcoal would enhance the preservation of the other organic matter accumulating in the sediments.

Charcoal counting, while relatively easy, is tedious and many studies sample pollen and micro-charcoal (<125 micron) at relatively coarse intervals (low resolution), often only counting one sample per 500 years over a total time scale of perhaps 12,000). Data from such studies should be used with caution.

Macro-charcoal is 250 micron or larger, and is generally derived from local sources at the site of deposition. High resolution studies of both macro and micro charcoal are more useful for providing evidence for change in fire regime, since they sample the soil profile more intensively. With continuous sampling and a well established chronology, charcoal influx can be analysed with time series to provide an indication of fire recurrence intervals (Higuera *et al.* 2007).

An example of the use of charcoal to interpret fire regimes is provided by Dodson *et al.* 1994 (Figure 2). Here the results showed a lower proportion of charcoal in the sediments at Club Lake dating from between the years 1600 and 1850, around the time of the little ice-age. The quantity of charcoal increased in 1850 at the time graziers commenced their frequent burning of the high country in an attempt to improve the vegetation for grazing. With the decline in grazing after the Second World War, and the declaration of the area as a national park, the quantity of charcoal declined, indicating a reduction in fire frequency and extent. Interestingly prior to 1600 higher quantities of charcoal were present. This may be interpreted in several ways— either that the Aboriginal burning activities had been greater in the 200 years prior to 1600 or else that the vegetation and fuel loads were different, leading to differences in the likelihood of fire.

Data by Justine Avery for a *Sphagnum* bog at Snowy Flat burnt by a patchy fire in 2003 showed that only the patches burnt in the fire had charcoal in the surface samples. Micro-charcoal was not found in most of the unburnt areas despite samples being only a matter of a few metres from the edge of the burn area. The record back though time at this site shows a reduction in charcoal in the past 300-400 years, despite a known history of frequent fire between 1850 and 1950 (Figure 3). The absence of charcoal in the recent record may relate to the increased abundance of *Sphagnum* and the lack of transport of charcoal into the bog deposits here for that reason (Hope *et al.* 2009).

Examples of charcoal analysis which show more promise with respect to interpreting fire history include the fine resolution core from Bega Swamp (1025 m altitude in southern New South Wales). This was sampled at 2.5 mm intervals. The results show that the number of samples including charcoal has increased since European settlement confirming other studies that graziers burnt more frequently than the Aborigines before them in the Australian high country.

Black *et al.* 2007 report on a high resolution macro-charcoal record from three sites in the Blue Mountains, NSW

They discern a general climatic control with low charcoal in the early Holocene and an increase after 6000 years ago that reflected increasing summer insolation. However in two sites late Holocene fire is reduced which they suggest may reflect careful fire management by aboriginal groups.

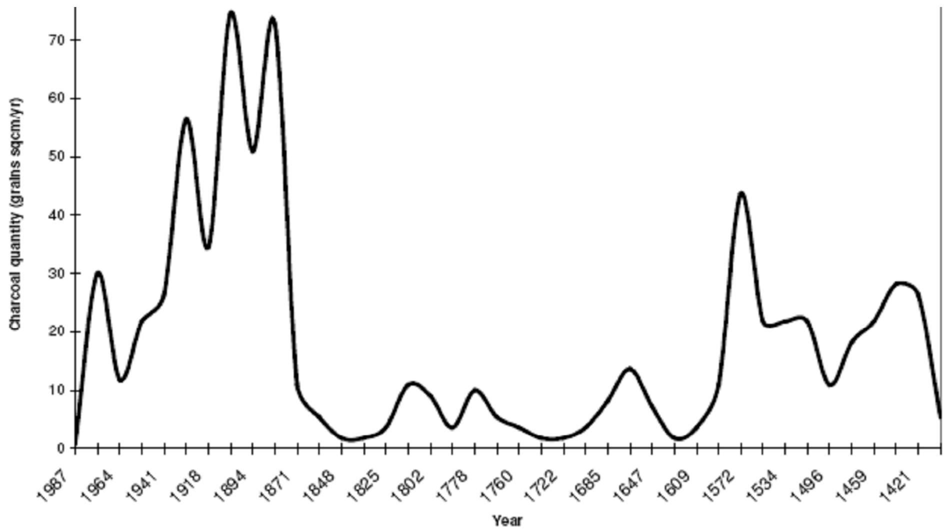

Figure 2: Fire frequency/intensity through time in the vicinity of the Alpine areas of Kosciusko National parks as indicted by charcoal deposits in Club Lake. Data taken from Sharp 1992, also published in Dodson *et al.* (1994). This figure was taken from Zylstra (2006) Fire history of the Australian Alps. Prehistory to 2003. Australian Alps Liaison Committee.)

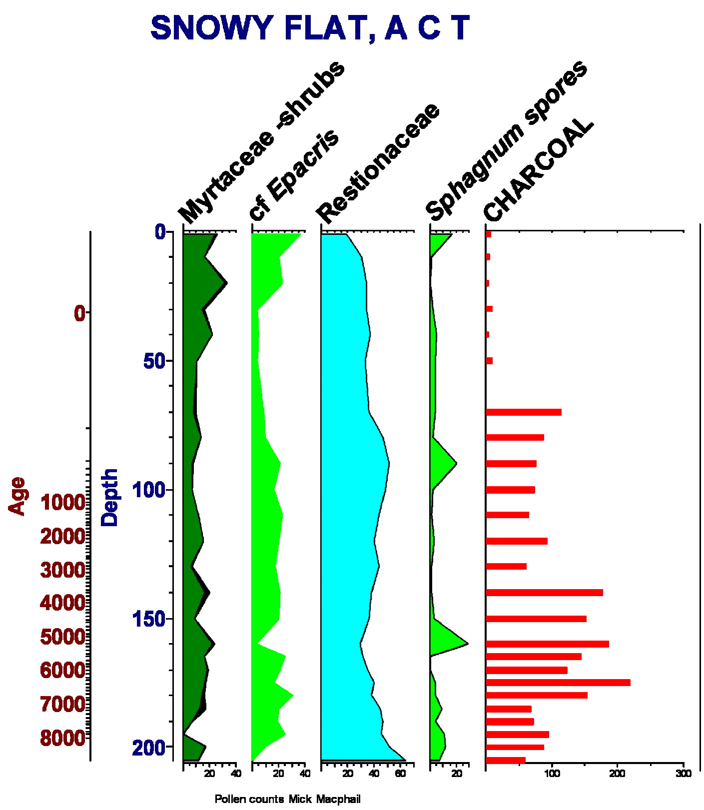

Figure 3: Changes with time in pollen composition at Snowy Flat. Pollen counted by Dr Michael Macphail.

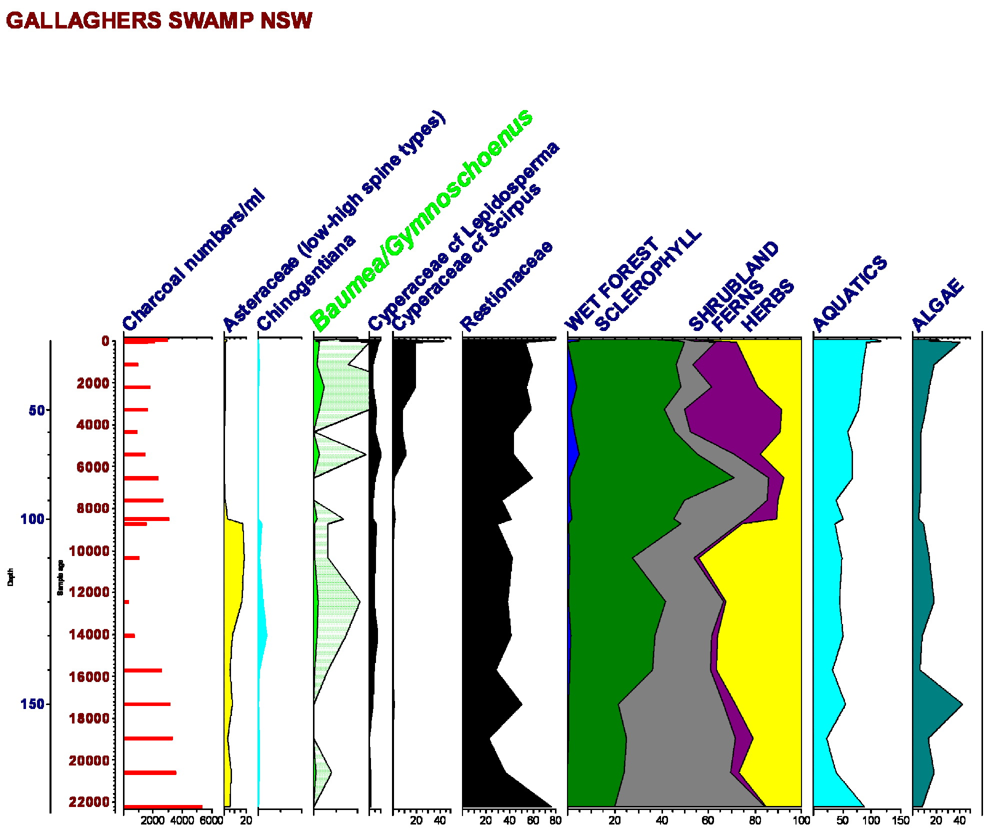

Figure 4: Pollen analysis by Dr Michael Macphail of a core taken by Kerry Tompkins from buttongrass moorland at Gallaghers Swamp, New South Wales.

A buttongrass moorland through time

Michael Macphail`s pollen analysis of core from a buttongrass moorland at Gallaghers swamp, west of Wollongong at 400 m altitude on Sydney Sandstone is the first site at which *Gymnoschoenus* pollen has been carefully discriminated from other sedges. The pollen diagram (Figure 4) shows that the buttongrass moorland (light green on pdf version, left of black infilled area for Cyperaceae cf *Lepidosperma*) has been in almost continuous occupation at the site for the past 22,000 years despite changes in fire and climatic regimes. Unfortunately there has only been a low resolution study of the charcoal and this does not provide much information about the fire history in relation to the increase and decline of buttongrass at the site. However buttongrass is present at the same time that Asteraceae and *Chionogentiana* species are prominent, an indication that the cool conditions of the glacial maxima were not a problem for it. A decline in buttongrass in the early Holocene correlates with increasing tree pollen. It seems likely that the moorland became patchy at this time as forest established on drier sites. After 6000 years ago fire is prominent in the record and tree pollen is declines. Buttongrass then increases and holds the site until the present.

This reconstruction, though preliminary, suggests *Gymnoschoenus sphaerocephalus* is resilient and stable through a range of climatic regimes. It appears to respond to fire rather than leading it. More detailed study of continuous charcoal and pollen records will be needed to fully establish the history of buttongrass in eastern Australia, but the potential has been demonstrated.

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Buttongrass

by 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.

Freshwater red algae in Tasmanian streams

Timothy J. Entwisle

Botanic Gardens Trust, Sydney, NSW 2000

Most of the world view algae as a menace: look at the signs in the Hobart airport warning of the weedy diatom *Didymosphenia geminata*, or the reaction to red tides that wash into the southern coast of Tasmania. Yet there is a fascinating and important native algal flora in the streams and lakes of Tasmania. I've been collecting algae from Tasmanian streams sporadically over 25 years, particularly the red algae, common inhabitants of streams flowing through buttongrass moorlands. However the most intriguing finds were made not by me, but by the ecologist Dave Ashton on a Christmas walk along the Western Arthurs, and limnologist Peter Tyler in one of his many forays to original Lake Pedder.

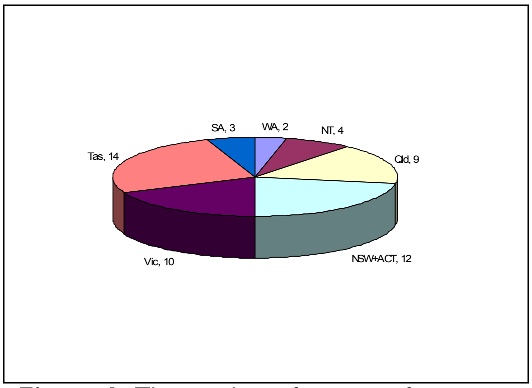

Figure 1: The number of species of freshwater red algae recorded from each State and Territory in Australia (data from Entwisle *et al.* 2007).

Of the 26 species of what we call the 'primary' freshwater water algae in Australia, 14 occur in Tasmania – this is more than any other State or Territory (NSW is second with 12 species). Tasmania has five species endemic to the island, and possibly a couple more to come. Two sit on either side of Bass Strait, and another five occur in Tasmania, the south-east corner of the Australian mainland and New Zealand.

Psilosiphon scoparius is a single species, in a single genus within the family Psilosiphonaceae. It grows abundantly in south-western Tasmania, in two disjunct locations south of Sydney and in one stream on the northern tip of the North Island of New Zealand. Until my last visit to Tasmania, all the know localities for *Psilosiphon* in Australia were at least a half hour walk from any made road.

Of the other red algae – mostly in the genus *Batrachospermum* (the 'frog spawn' algae) – many have been found in remote wilderness as well as under main road crossings. A couple, however, are restricted to streams around Bathurst Harbour. More species are sure to be discovered as new areas are surveyed. *Batrachospermum diatyches* was first discovered on the shore of the original Lake Pedder, but has since been found near Lake Dove and another high altitude lake.

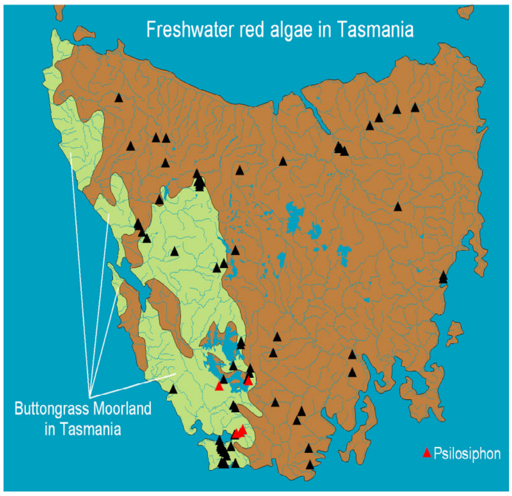

Figure 2: Collection localities recorded for freshwater algae in Tasmania (data from Australia's Virtual Herbarium). Black triangles represent collections of *Batrachospermum, Sirodotia* and *Nothocladus*. Red triangles represent *Psilosiphon*.

Although there have good collections of algae from the lakes and streams of Tasmania, much of the identification has been at alpha taxonomy level – some brief comparative work within Australia, or sometimes just attaching a name of best fit. Further collecting, taxonomic study using DNA and morphology, and where available comparison with Type collections, will result in a better understanding of endemism, rarity and evolutionary significance. This will in turn contribute to better conservation of the freshwater algal flora, to Tasmania's aquatic habitats, and to ecosystems such as the buttongrass moorlands.

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Buttongrass Valley

By Oberon Carter

Breathe in the mist, and breathe out the cool of the morning,
As yellow tailed blacks turn and sever the cloudy sky,
You feel all this space, but you're afraid to take it all in,
Alone, enraptured by the stillness,

Of a place that can break any fall,
A place that's best left alone,
But aside from the obvious,
It's just you- alone with the elements,

So you arch yourself down- To the grin of the valley,
Completely aware – Of each slip and each roll,
Wash the aches of your heart- Heal the bones on your body,
Ease the yearnings that start - In the foot of your soul,

Seek to persist, after thousands of years are done passing,
The delicate wisps of blue orchids that stand in the grass,
They're sealed like a fist, through the heat of a middle-day sunburn,
One shines out amongst the brilliance,

Of a place that can break any fall,
A place that's best left alone,
But aside from the obvious,
It's just you- out wild with the elements,

So you arch yourself down – To the buttongrass valley,
Lie and rest till you sleep – In contented defeat,
Handing sips from the dreams- Of a whispering river,
Drawing shadowy lines- Where the earth and air meet.

Lichens: an overlooked Lilliput in Tasmania's buttongrass moorlands

Gintaras Kantvilas

Tasmanian Herbarium, Hobart TAS

Abstract

Lichens contribute significantly to the biodiversity of buttongrass moorland and, in some communities, they may even comprise the dominant ground cover. Species colonise the peaty soil, pebbles and large rock outcrops, and the larger trees and shrubs. Whereas a few lichens are more or less confined to buttongrass moorland, most also occur in other, usually adjacent vegetation types, especially in alpine and subalpine heathland, cool temperate rainforest or open eucalypt forest. Although most buttongrass lichens display predominantly Southern Hemisphere distributions, there are distinct floristic and ecological similarities between Tasmanian moorlands and related blanket bogs and moorlands in the Northern Hemisphere. The long-term impact of fire in Tasmania's buttongrass moorland is difficult to predict. Lichens are clearly very fire-sensitive, but their abundance in at least some communities is proof of their resilience and persistence in the face of regular burning. Of critical importance is the maintenance of a diversity of community types, habitats and fire regimes to ensure that refugia and suitable habitats are preserved.

Introduction

Lichens are very prominent in some buttongrass moorland communities, occasionally comprising the dominant ground cover. However, they are rarely considered when management regimes for buttongrass moorland are being defined.

The first detailed synopsis of the lichen flora of Tasmania's buttongrass moorlands was undertaken during a State-wide survey and classification of this vegetation formation (Jarman *et al.* 1988). Lichenological results were published by Kantvilas & Jarman (1988) who recorded 89 species and discussed their distribution and ecology. Prior to this, the only published information on buttongrass lichens was brief, incomplete and very generalised (Bratt 1976, 1978).

In the decades since the State-wide survey, no further formal lichen survey or ecological work has been undertaken, but research on the taxonomy of the flora has proceeded apace. Numerous additional species have been recorded as a result of casual visits and collecting. 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), and the prominent moorland genus *Siphula* has been revised (Kantvilas 1996, 1998). Nomenclatural changes have also impacted severely on the initial inventory.

Major lichen habitats in buttongrass moorland, distribution patters and conservation and management of the lichen flora were discussed by Kantvilas (2007). The aim of the present paper is to update and revise the inventory of lichens recorded from buttongrass moorland.

Nature of the flora

Despite its prominence, there is probably no buttongrass moorland lichen flora *per se*, nor a lichenological "*Gymnoschoenus*-equivalent" that defines the vegetation. 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

- rather weedy species able to cope with disturbance such as fire and living in rather dynamic conditions where succession occurs quickly and involves often rapid regrowth of vascular plants and concomitant changes in microhabitats; or
- species able to persist in tiny, highly localised refugia in the face of such disturbance and successional change.

Composition of the flora

The revised inventory now contains 125 species (Appendix 1). However, due to the nature of the flora (see above), the definition of a 'buttongrass moorland lichen' remains rather arbitrary, and accounts of the lichens of adjacent vegetation, especially alpine communities (Kantvilas & Jarman 1991, Kantvilas 1995) and rainforest (Jarman & Kantvilas 1995), are highly relevant because some of their component lichen species may occur within moorland in localised pockets of scrub or on larger rocky tors.

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Editor's note

Part of the presentation by Gintaras Kantvilas at the buttongrass moorland management workshop in July 2007 was published within 'buttongrass moorland — conservation and management', a special theme-edition of *Australasian Plant Conservation Bulletin* (Kantvilas 2007). This article described lichen communities within buttongrass moorland in terms of their phytogeography, conservation management and important habitats.

Appendix 1: Revised inventory of lichens recorded in Tasmanian buttongrass moorland.

Ainoa mooreana (Carroll) Lumbsch & I. Schmitt

Arthrorhaphis grisea Th. Fr.

Austroblastenia pauciseptata (Shirley) Sipman

Baeomyces heteromorphus Nyl. ex C. Bab. & Mitten

Bunodophoron australe (Laurer) A. Massal.

B. ramuliferum (I.M. Lamb) Wedin

Cladia aggregata (Sw.) Nyl.

C. deformis Kantvilas & Elix

C. dumicola Kantvilas & Elix

C. fuliginosa R. Filson

C. inflata (F. Wilson) D.J. Galloway

C. moniliformis Kantvilas & Elix

C. mutabilis Kantvilas & Elix

C. retipora (Labill.) Nyl.

C. schizopora (Nyl.) Nyl.

C. sullivanii (Müll. Arg.) Nyl.

Cladina confusa (R. Sant.) Follm. & Ahti

C. mitis (Sandst.) Hustich

Cladonia adspersa Mont. & Bosch

C. angustata Nyl.

C. capitellata (Hook.f. & Taylor) C. Bab. var. *capitellata*

C. capitellata var. *squamatica* A.W. Archer

*C. chlorophae*a (Flörke ex Sommerf.) Sprengel

C. corniculata Ahti & Kashiwadani

C. crispata (Ach.) Flotow var. *cetrariiformis* (Delise) Vainio

C. cryptochlorophaea Asah.

C. enantia Nyl.

C. gracilis (L.) Willd. ssp. *tenerrima* Ahti

C. kuringaiensis A.W. Archer

*C. merochlorophae*a Asah.

C. murrayi W. Martin

C. neozelandica Vainio

C. ochrochlora Flörke

C. pleurota (Flörke) Schaer.

C. praetermissa A.W. Archer var. *praetermissa*

C. pyxidata (L.) Hoffm.

C. ramulosa (With.) Laundon

C. rigida (Hook.f. & Taylor) Hampe var. *rigida*

C. sarmentosa (Hook.f. & Taylor) C.W. Dodge

C. scabriuscula (Delise) Nyl.

C. southlandica W. Martin

C. subsubulata Nyl.

C. sulcata A.W. Archer var. *wilsonii* (A.W. Archer) A.W. Archer & J.K. Bartlett

C. ustulata (Hook.f. & Taylor) Leighton

C. verticillata (Hoffm.) Schaer.

C. weymouthii F. Wilson ex A.W. Archer

Cystocoleus ebeneus (Dillwyn) Thwaites

Dibaeis arcuata (Stirt.) Kalb & Gierl

Flavoparmelia haysomii (C.W. Dodoge) Hale

Fuscidea australis Kantvilas var. *australis*

Haematomma nothofagi Kalb & Staiger

Hertelidea sp.

Heterodermia microphylla (Kurok.) Swinsc. & Krog

H. obscurata (Nyl.) Trevis.

Hypocenomyce australis Timdal

Hypogymnia lugubris (Pers.) Krog

H. tasmanica Elix

Hypotrachyna sinuosa (Sm.) Hale

Icmadophila splachnirima (Hook.f. & Taylor) D.J. Galloway

Lecanora farinacea Fée

Leifidium tenerum (Laurer) Wedin

Lithographa graphidioides (Cromb.) Imshaug ex Coppins & Fryday

Megalospora lopadioides Sipman

Menegazzia aeneofusca (Müll. Arg.) R. Sant.

M. confusa P. James

M. platytrema (Müll. Arg.) R. Sant.

Micarea isabellina Coppins & Kantvilas

M. magellanica (Müll. Arg.) Fryday

M. melaena (Nyl.) Hedl.

Multiclavula vernalis (Schw.) R.H. Petersen

Mycoblastus coniophorus (Elix & A.W. Archer) Kantvilas & Elix

M. dissimulans (Nyl.) Zahlbr.

Neophyllis melacarpa (F. Wilson) F. Wilson

Ochrolechia frigida (Sw.) Lynge

Omphalina umbellifera (L. ex Fr.) Quélet

Paraporpidia leptocarpa (C. Bab. & Mitten) Rambold & Hertel

Parasiphula complanata (Hook.f. & Taylor) Kantvilas & Grube

P. elixii (Kantvilas) Kantvilas & Grube

P. fragilis (Hook.f. & Taylor) Kantvilas & Grube

P. georginae (Kantvilas) Kantvilas & Grube

P. jamesii (Kantvilas) Kantvilas & Grube

Parmelia signifera Nyl.

Peltigera didactyla (With.) Laundon

P. dolichorhiza (Nyl.) Nyl.

Pertusaria flavoexpansa Kantvilas & Elix

P. gymnospora Kantvilas

Placopsis clavifera (I.M. Lamb) D.J. Galloway

P. gelida (L.) Lindsay

Placynthium nigrum (Huds.) S.F. Gray

Poeltiaria coromandelica (Zahlbr.) Hertel & Rambold

Protoblastenia calva (Dicks.) Zahlbr.

Pseudocyphellaria glabra (Hook.f. & Taylor) C.W. Dodge

Pycnothelia caliginosa D.J. Galloway & P. James

Ramboldia laeta (Stirt.) Kalb *et al.*

R. petraeoides (Nyl. ex C. Bab. & Mitten) Kantvilas & Elix

R. stuartii (Hampe) Kantvilas & Elix

Rhizocarpon geographicum (L.) DC.

Santessoniella rugosa Henssen & Kantvilas

Siphula decumbens Nyl.

S. fastigiata (Nyl.) Nyl.

S. gracilis Kantvilas

Siphulastrum mamillatum (Hook.f. & Taylor) Galloway

Siphulella coralloidea Kantvilas, Elix & James

Stephanocyclos henssenianus Hertel

Stereocaulon ramulosum (Sw.) Räuschel

Tasmidella variabilis Kantvilas, Hafellner & Elix var. *variabilis*

Thysanothecium scutellatum (Fr.) D.J. Galloway

Trapeliopsis colensoi (C. Bab.) G. Schneider

Umbilicaria cylindrica (L.) Delise ex Duby

U. polyphylla (L.) Baumg.

Usnea molliuscula Stirt.

U. oncodes Stirt.

U. torulosa (Müll. Arg.) Zahlbr.

Verrucaria tuberculiformis P.M. McCarthy & Kantvilas

Wawea fruticulosa Henssen & Kantvilas

Xanthoparmelia alexandrensis Elix & J. Johnst.

X. amplexula (Stirt.) Elix & J. Johnst.

X. australasica D.J. Galloway

X. flavescentireagens (Gyeln.) D.J. Galloway

X. mougeotina (Nyl.) D.J. Galloway

X. neotinctina (Elix) Elix & J. Johnst.

X. scabrosa (Taylor) Hale

Xanthoparmelia stygiodes (Nyl. ex Cromb.) O. Blanco *et al.*

X. tegeta Elix & J. Johnst.

X. xanthomelaena (Müll. Arg.) Hale

From one quaking tussock to the next:

Walkers and buttongrass

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Buttongrass is an extraordinarily successful sedge, and the centre-piece of a plant community that covers more than a million hectares of Tasmania. Found from coastal plains to alpine moors, it is arguably the vegetation type most often associated with the wilds of Tasmania. Yet encounters between early European explorers and buttongrass seldom led to appreciative comment or lyrical description. T.B. Moore is not atypical in referring to it in 1887 as "the hated button grass". He and others quickly learned what Aboriginal hunters had known for millennia: that fire could quickly – if temporarily – clear vast areas of it.

Later more poetic explorers, such as Charles Barrett in the 1940s, continued to damn it with faint praise, referring to it as "drab-coloured button-grass". Many scientists persisted in the same vain, seeming to find fault with this vegetation because it was difficult to move through while studying. The association of pejorative adjectives with buttongrass – "hated", "drab", "boggy", "impenetrable", "leech-ridden" – has gone on to pervade the vocabulary of the bushwalking community. It might even be argued that buttongrass has become a dread adjective in its own right.

This paper explores some of the written accounts of a plant and the people who walk amongst it. It briefly considers some alternative viewpoints, both scientific and poetic. And it asks whether a less anthropocentric, more wide-eyed perspective might complement science in yielding a greater appreciation among all who come face-to-face with Gymnoschoenus sphaerocephalus and its wider biotic community.

Here's a curious thing: a bushwalker at a buttongrass management workshop. Surrounded by people who love the stuff, shouldn't I feel a bit like a train-spotter among railtrack engineers? Or a swimmer among hydrologists? Surely for bushwalkers, buttongrass is nothing more than stuff you have to travel over or through, at best an inconvenience, at worst a hated impediment. That kind of thinking has quite a tradition. Consider the following accounts from travellers over the last couple of centuries.

A track cutter's attitude to buttongrass is typified by D. Jones in 1881.

> *"Whenever we could get a fine day we burned what we could, and the benefit to us was incalculable, rendering the travelling comparatively easy."*

Fellow track cutter Thomas Bather Moore and his helpers similarly "put a match" to great swathes of moorland. He describes a typical instance near Frenchmans Cap in 1887.

> *"We found the fire had done excellent work and was still blazing ahead . . . The fires burned for a week, and cleared the hated buttongrass and bauera splendidly, in all directions for miles."*

From the same year here's the more genteel James Backhouse Walker in his travel book 'Walk to the West'.

> *"The worst of button grass is that the tussocks are so placed that [it] is equally difficult to walk between them as on them, and as the boggy ground is generally undermined by 'crabholes' made by a little land-lobster, you find yourself now twisting your ankle by an insecure tread on the top of a springy tussock, now plunging over the top of your boot-tops into a mud hole, each a sufficiently exasperating alternative. A few miles of this sort of walking tends to become monotonous."*

Onwards to the 20th century, at the beginning of which photographer JW Beattie made a trip into "the Barn Bluff country". He and his party are benighted on the buttongrass plains beneath Mt Oakleigh, an experience he doesn't appear to have enjoyed.

> *"On we went … stumbling and splashing, moving slowly in single file. Sometimes down would go one of the pack horses, and the procession would stop until the order was passed along to move on again, then more stumblings, shoutings, boggings right up to the knees, complete collapses over the wretched grass clumps, wringing wet, and still on we had to move."*

As the century proceeds, the feelings persist. Dr C.S. Sutton's 1928 sketch of the vegetation of Cradle Mt. curtly tells us that buttongrass *"occupies much of the wet, sour ground in the valley."* Even the customary lyricism of Charles Barrett, in his 1944 celebration of Tasmania entitled "Isle of Mountains", falls flat before our famous sedge. During a walk he describes *"millions of little flower faces brightening the drab-coloured button-grass which flourishes in Cradle Valley."*

Keith Lancaster's report of a Launceston Walking Club trip to Frenchmans Cap" in 1951, reinforces this desire for botanical diversity.

"The stretches of button grass along the Loddon Plains had their monotony broken by occasional *Xyris, Patersonia* and *Stylidium* blooms and several little clusters of the delicate little violet *Utricularia*."

ET Emmett in "Tasmania By Road and Track" describes a trip on the Overland Track in the late 1940s.

> *"After lunching by the sandy shore of a pine-fringed lake all we had to do was to stumble through five miles of button-grass, cross a couple of rivers and follow a real track that leads to Cynthia Bay at the south end of Lake St Clair."*

Another public servant, former Conservator of Forests L.G. Irby, had a truly original take on what to do with buttongrass. He has left us an intriguingly titled two-volume work, "*Conquest of the Button Grass Plains and Heathlands of Tasmania"*. In it he outlines his experiment in transforming buttongrass plains into agicultural land. He claims "*that excellent pastures can be established at a cost, ex fencing and farm buildings, not exceeding twenty pounds per acre"* (this in 1955 currency). He also contends that these "*formerly treeless wastes*" could be turned into conifer forests, producing millable trees with heights of 70 feet in 14 years. (I would suggest that leaking this report to Gunns might not be a good idea if you value the retention of buttongrass moorland as "*treeless wastes*".)

Moving closer to our own era, C.J. Binks in his 1980 book 'Explorers of Western Tasmania' gives a long and fair description of buttongrass, and its prevalence in western Tasmania. But in flatly disagreeing with Irby's hopes, he declares that "*button grass has so far defied efforts to tame it for man's use." He sums up tartly: it is "useless to man."*

Botanist I.J. Edwards, in 'The South-West Book' (1983 edition) informs us buttongrass is the climax species on very poorly-drained sites in the south-west. His first-hand experience of walking there would be backed up by many a bushwalker. He tells us

> "*progress over such an area is quite hazardous, as one must jump from one quaking tussock to the next.*"

Let's hear again the litany of buttongrass descriptors we have so far uncovered: *hated, useless, wretched, monotonous, drab-coloured, insecure, exasperating, hazardous, sour, waste.* If buttongrass were a child raised on that kind of language, you would fear for its self-image. Can we say nothing more positive about it?

With some difficulty I have uncovered a few passages that might be thought to reflect a little more favourably on buttongrass. Let's return to 1887 and James Backhouse Walker, who eventually started to really see the buttongrass, even while calling it "*a curious production of nature*". He continues:

> "*A walk across the Western Country affords large opportunities for studying it at leisure. It . . . is not particular about its abode. It is a thin leaved yellow rush growing in thick tussocks 2 or 3 feet across, and each tussock bearing a few flower stalks some feet long and about as thick as a stout knitting needle, adorned at the top by a seed vessel like a rounded marble or button – from this button it derives its name."*

At least he is really looking now, and eventually he can't help but see some poetry in the views around the Navarre Plains. "*The most striking were the precipitous bluffs and peaks of Mount King William rising in our front from dark green forest, beyond a broad foreground of button-rush plain glowing with every blended tint of yellow, red and brown.*"

A very different poetry emerges a century later from Australia's unofficial poet laureate, Les Murray. After a visit to Tasmania in the 1980s, he wrote "Bent Water in the Tasmanian Highlands", a poem that has been widely praised and anthologised. I suggest you don't try to understand this poem, but rather just go with its flow of images and words.

> *"Flashy wrists out of buttoned grass cuffs, feral whisky burning gravels,*
>
> *jazzy knuckles ajitter on soakages, peaty cupfuls, soft pots overflowing,*
>
> *setting out along the great curve, migrating mouse-quivering water,*
>
> *in the high tweed, stripping off its mountains to run faster in its skin."*

Murray goes beyond simply seeing. He is having total sensory immersion in buttongrass. Perhaps the first step to us achieving something similar is the simple act of standing. I literally mean standing still in the middle of buttongrass. Is there anything that can give you a greater sense of arrival in the Tasmanian wilderness than being surrounded by buttongrass? Consider what else you might experience. If it's a hot day, you may feel the stored-up warmth of the peat radiating out towards you, the buttongrass stalks becoming antennae that focus the heat onto you. Or in the rain, cease your talk, soften your breath and listen. Can you hear the dripping of water from the stalks? Do the droplets runnelling down towards the heart of the grass make a sound? And when saturation point is reached can you make out any trickling, burbling or squelching coming from the earth beneath you? If you're up early on a still morning, look for bedewed webs spanned between the patient stalks. Not one, not a few, but hundreds and thousands of exquisite ephemeral arachnid artworks.

When you've been in its midst for a while, you may even find yourself removing your hat in a mixture of awe and admiration for what this vegetation community has achieved. On Friday many of us will have a chance to do just this. For an hour or two we will stand out in the south-west's elements, think ourselves brave in our thermals and "*Goretices*" (that's the official plural of Goretex). And then we'll scurry back to our bus and return to warm and comfortable habitats. 24 hours a day, 7 days a week, every week, every year, every decade, every century, every millennium for the last several thousand millennia, with no time off for good behaviour, these moorland communities have stood out there. Through sun and snow, freeze and thaw, flood and drought, fire and wind, buttongrass has not only stood, but thrived and spread to become the signature floral species of the south-west. It might not be greatly loved, but you have to admire its persistence and success (a bit like John Howard, I suppose).

Having gone from the sublime to the gor' blimey, I would like to finish with reflections on the lighter side of buttongrass. I want to introduce you to three games that you might try when you're next out among the buttongrass. The first is a time-honoured game, and there are still some who like to play it, even if the correct attire is becoming harder to procure. My experience of this game, which I will call "*Where's Wally?*", dates back to the early 1980s. Picture the scene: my walking friends and I are in the Cuvier Valley, to the west of Lake St Clair. Remember that in this era Goretex is still a dormant synapse in some chemist's brain, and we, like most bushwalkers, have been outfitted at the nearest army surplus store. Picture us in our khaki woollen trousers, our drab woollen jumpers, hand-knitted woollen beanies, ex-army boots and gaiters. As the rain descends I stop and drop my khaki canvas H-frame haversack, and reach inside for my state-of-the-ark oilskin.

But my companions have moved on into the gathering gloom. When I've finally got my jacket on, I look up to find that the've disappeared. Misty rain blurs whatever distinction there may have been between their clothing and the surrounding buttongrass. As an aside, I will confess that I've never actually walked with a Wally, but "*Where's Wally?*" sounds better than "*Where's Jim?*" or "*Where's Ken?*". And the effect is the same. My khaki-clad companions have become invisible against the buttongrass. So the aim of the game is simply to find your companions again. After 5 minutes of trying – back there in the Cuvier Valley circa 1981 – I began to feel a bit like a member of the legendary Heckarwee tribe. A congenitally short-statured tribe, averaging only 4 feet in height, they were said to wander around the 5 foot-high grasslands of Central America saying "*We're the Heckarwee!*"

The second game sounds similar, but there are key differences. The aim of this game is to seek and find discarded footwear in buttongrass bogs. I call this game "*Vhere's Volley*?" for reasons that might require a little explanation. For decades now walkers from mainland Australia, in particular those from NSW, have run a noisy campaign against traditional leather walking boots, preferring Dunlop's lightweight tennis shoes known as Volleys. Here's an early example of their propaganda taken from the book 'Paddy Pallin's Bushwalking and Camping' (1985 edition, written by Tim Lamble, pp 48–49). "*Intrinsic in the protection offered by a boot is the lack of care needed to place the foot on the ground. The picture of a relentless army, crunching its way across the country, is not far removed from the practice of some walkers. The lighter shoe reminds its wearer of the sensitivity of both foot and countryside.*"

This high-sounding rhetoric dissolves before the acidity of the peaty mud underlying buttongrass, which will soon remind the wearer that Dunlop Volleys were never made to stand up to Tasmanian conditions. They deteriorate rapidly on such trips, soon gaping, and leaving the tender mainland foot open to the elements. Even legendary NSW Volley walker Dave Noble confessed as much when he told us bushwalking that Volleys "*tend to rot a bit quicker in the acidic buttongrass water - and you can only get about two weeks solid walking out of a pair.*" But more than that, Volleys can't always be successfully extracted along with the foot when you step into a deep mudhole.

Thus do buttongrass moorlands become graveyards for inadequate footwear, and deliver us the wonderful game: "*Vhere's Volley*?" For this game you simply need a rubber-and-canvas-seeking equivalent of a metal detector, and a pen and paper to keep score. I admit I haven't tried it out yet, but I would envisage world record scores coming out of places like the Cuvier Valley.

The third and final game very neatly combines botany and ornithology. There's a delightful synchronicity about it in our current context, as it features a bird that is almost totally associated with buttongrass. I'm referring to the ground parrot (*Pezoporus wallicus*). The alert among you may already be anticipating the name of this game, but I would urge you to hold your council for just a moment. My experience of this game is restricted to the area around Melaleuca in the south-west, but I understand it can be played in many other parts of western Tasmania, even at the Strahan airfield.

The key to the game is to find one of these birds before it finds you. This is easier said than done. I first played it on the boardwalk between Melaleuca and Cox Bight. As I walked along in a boardwalk-induced trance, I was startled by a sudden rush of wings. A brownish/greenish blur arced across the track, at a very low trajectory, and settled into the buttongrass some 20 metres ahead. Each time I came near, it would repeat the performance, doing so for well over a kilometre. And yet in all that time, despite having a good bead on the whereabouts of the parrot, I could never spot it before it flew off.

Of course the game is called "*Where's Wallicus*?", and I would encourage you all to try it out when next in the area.

The dynamics of the boundary between lowland buttongrass moorland and wet-eucalypt forest in southwest Tasmania

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Abstract

The vegetation transition between buttongrass moorland, wet-scrub and wet-eucalypt forest in southwestern Tasmanian at different times since fire was examined. Sites had been burnt two, nine, 19 and 40 years prior to the study. The wet-scrub ecotone between buttongrass moorland and wet-eucalypt low forest was found to be structurally and floristically distinct and formed two zones: an outer-boundary which was closely related to the buttongrass moorland, and an inner-boundary which was closely related to the wet-eucalypt forest. With increasing time since fire, buttongrass moorlands are likely to be transformed structurally into a community which is floristically and structurally similar to the outer-boundary scrub zone and this transformation will be fastest adjacent to wet-scrub margins. While current theories of ecological drift are supported by this work, the time periods required for succession to occur are slower than those proposed in Jackson's 1968 ecological drift theory.

Introduction

Vegetation - fire interactions are a critical element of vegetation dynamics in southwest Tasmania and have been discussed in the literature for over 70 years (e.g. Davis 1940, Gilbert 1959, Jackson 1968, 1978, Mount 1979, Bowman & Jackson 1981, Brown & Podger 1982, Bowman *et al.* 1986, Jarman *et al.* 1988a, 1988b, Pemberton 1989, Balmer 1990, Brown 1996, 1999, Jackson 1999b, Jackson & Brown 1999, Brown *et al.* 2002, King 2004a, 2004b, King *et al.* 2006, 2008). The lowland vegetation of this region forms a complex mosaic ranging from highly fire-tolerant, fire-dependent and fire-promoting buttongrass moorlands through increasingly fire-sensitive but still fire-dependent wet-scrub and wet-eucalypt forests to the fire-sensitive, fire-intolerant and fire-retarding rainforest communities. In addition, vegetation surveys throughout southwest Tasmania have shown that there is a marked change-over in the floristics between these community types (e.g. Jarman *et al.* 1984, 1988b, Kirkpatrick & Dickinson 1984, Kirkpatrick *et al.* 1988, 1993).

In southwest Tasmania, the transition in vegetation type between buttongrass moorland and wet-eucalypt forest contains an intermediate wet-scrub zone in most, if not all, situations (Brown & Podger 1982, Balmer 1990, Brown *et al.* 2002). However, field observations by the authors of this paper suggest that this wet-scrub zone is not homogeneous in its structure and species composition but instead itself appears to form distinct zones.

Therefore, the aim of this study was to examine the boundary between buttongrass moorland and wet-eucalypt forest in low fertility sites in southwest Tasmania to determine whether the boundary was dynamic or static, and identify mechanism(s) by which community type could be transformed. To do this, the boundary and its soil types were examined in the field and the growth rates of the dominant species examined under glasshouse conditions.

Methods

Study site characteristics

A range of sites located along the Gordon River and Scotts Peak Roads in southwestern Tasmania was selected such that sites were as similar as possible to each other with the exception of time since the last fire. At the time the study was performed, the fire ages of the sites ranged from two to 40 years (Table 1, Marsden-Smedley 1998).

The total distance between the two most distant sites, Edgar and Airstrip Road, is about 20 km. All sites had low slope angles (less than 5°), were underlain by Precambrian derived quartzitic gravel (Brown *et al.* 1982, Turner *et al.* 1985) and were about 325 m above sea level. At all of the sites the transition between lowland blanket buttongrass moorland (type B1a of Jarman *et al.* 1988b) through the tea-tree and paper-bark dominated boundary community to the wet-eucalypt forest community type dominated by West Coast peppermint (type B12b of Jarman *et al.* 1988b) was examined. The locations, fire ages and types of data collected at each site are shown in Table 1 and Figure 1.

In this region, buttongrass moorland tends to be dominated by *Gymnoschoenus sphaerocephalus* (buttongrass), *Leptospermum nitidum* (shiny tea-tree), and/or *Melaleuca squamea* (swamp paper-bark) frequently with *Leptospermum scoparium* (manuka) subdominant (Jarman *et al.* 1988b). Wet-scrub tends to be dominated by *L. scoparium, Melaleuca squarrosa* (scented paper-bark) and/or *Leptospermum glaucescens* (Moscal 1981, Jarman *et al.* 1982, 1988b). Wet-eucalypt forest tends to be dominated by *Eucalyptus nitida* (West Coast peppermint) with *M. squarrosa, L. scoparium* and/or *L. glaucescens* subdominant (Moscal 1981, Jarman *et al.* 1982, 1988b, Kirkpatrick *et al.* 1988). The soil types that occur in these different vegetation types have been described by Pemberton (1989). Species authorities follow Buchanan (2007).

Vegetation transects

At each of the sites (Table 1, Fig. 1) four transects were sampled using two-by-two metre plots. Each of these transects contained between eight and 12 plots and was orientated at right angles to the boundary. In each plot, vascular species maximum height and cover (Braun-Blanquet index values, see Mueller-Dombois and Ellenberg 1974) were recorded. The transect data were analysed using non-metric multi-dimensional scaling (MDS).

Soil variation by vegetation zone

The variation in soil type across the boundary from buttongrass moorland to wet-eucalypt forest was examined at eight sites located within close proximity to each other along the Scotts Peak Road (Table 1). Four blocks of soil (each 40 x 30 x 15 cm deep) were collected from each site from buttongrass moorland, the outer part of the wet-scrub boundary, the inner part of the wet-scrub boundary and from the wet-eucalypt forest. Soils were described using the methods of McDonald *et al.* (1984) and the soil depth above the underlying quartzite gravel, pH and organic content were measured. Total soil depth was estimated from the average depth of centre point and each corner of the plot by pushing a probe into the soil until gravel was felt. Soil pH was determined by taking 20 ± 0.1 g from the uppermost soil horizon (P1 horizon of McDonald *et al.* 1984) and placing it in 100 ml of deionised water for 60 minutes, then macerating for 30 minutes, allowing to settle for 60 minutes and then recording the pH from just above the level of the settled material using a standardised Metrohm Herisau E588 pH meter. Soil organic content (% of dry weight) was determined by loss on ignition at 520°C for eight hours. The calculated soil organic contents were not corrected for soil clay content.

Seedling growth dynamics under glasshouse conditions

The seedling growth rates for *Leptospermum nitidum, L. scoparium, L. glaucescens, Melaleuca squamea, M. squarrosa* and *Eucalyptus nitida* were examined on different soil types under glasshouse conditions. Seed capsules of each of these species were collected and the number of viable seeds per gram of the seed and chaff mixture determined by germinating set weights of the mixture at a range of temperatures (5°, 7.5°, 12.5°, 17.5°, 20° and 22.5°C) on a 16/8 hour light/dark regime for 32 days. Of the species tested, only *L. glaucescens,* had a stratification requirement (Marsden-Smedley 1990).

Each of the soil blocks collected from the field was steam sterilised at 121°C and 100 kPa for 60 minutes in order to prevent the regeneration of any plants present in the soil block. The soil blocks were then placed in plastic boxes in a glass house. The soils from the outer part of the boundary, inner part of the boundary and wet-eucalypt forest were allowed to free drain while the buttongrass moorland soils were kept saturated in order to replicate naturally-occurring conditions. Each soil block was divided into 12 equal-sized compartments and an estimated 25 seeds of each species were placed in each compartment. The experiment ran from late May 1990 through to mid January 1991. The seedling number was scored at 14 days and seedling number and height was scored at seven day intervals from 21 to 63 days and then at 77, 112, 147 and 243 days. During winter the natural light regime was supplemented with incandescent and fluorescent lights for about four hours each evening. The soil blocks were set up using a factorial split-plot design utilising the soil collection sites and then soil types (within collection sites) as sub-units. Where there were no seedlings in a cell, species height was treated as a missing value. During the analysis, seedling height was log-transformed in order to normalise its variance.

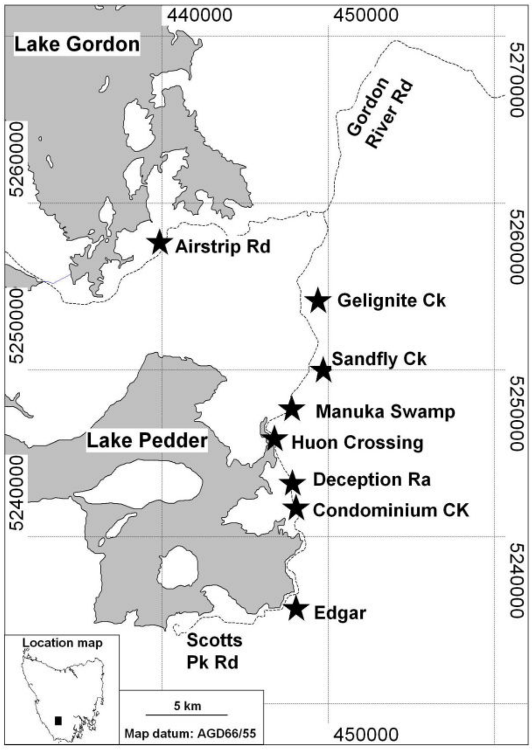


Figure 1: Study area showing sampling locations.

Table 1: Sites sampled in this survey — their location, sampling purpose and fire history.

Site	Grid reference	Data collected	Fire age and year		Known previous fires
Airstrip Rd	440000 5257900	transects	2	1988	1972, 1933/34, 1897/98
Sandfly Ck	448900 5250400	transects, seed collection	9	1981	1950, 1933/34, 1897/98
Gelignite Ck	449500 5251400	transects, soil type, seed collection	19	1972	1950, 1933/34, 1897/98
Edgar	447900 5236600	transects, soil type, seed collection	40	1950	1950, 1933/34, 1897/98
Condominium Ck	447700 5242400	soil type, seed collection	11	1979	1950, 1933/34, 1897/98
Deception Ridge	447500 5244200	soil type, seed collection	29	1961	1933/34, 1897/98
Huon Crossing	446900 5245700	soil type, seed collection	40	1950	1933/34, 1897/98
Manuka Swamp	448000 5248600	soil type, seed collection	57	1933/34	1897/98

Grid datum: AGD66 zone 55.

Results

Vegetation transects

The results of the ordination of the floristic data are shown in Figures 2 and 3. There are two trends in floristic variation. The first trend relates to floristic variation between sites, which appears to be largely confounded with fire age (Fig. 2), while the second trend appears to relate to the change in floristics associated with the transition between buttongrass moorland and wet-eucalypt forest (Fig. 3). In Figure 3, it also can be seen that the scrub species *Leptospermum nitidum*, *Melaleuca squamea* and *M. squarrosa* are intermediate between *Eucalyptus nitida* and *Gymnoschoenus sphaerocephalus* with *L. nitidum*, *L. scoparium* and *M. squamea* being closer to *G. sphaerocephalus* while *M. squarrosa* was closer to *E. nitida*. The ordination analysis indicated that the variation across the boundary zones observed in the field was orientated parallel to the transition in species type (Fig. 3).

Community structure

Community structure across the boundary at the different sites is summarised in Table 2. In only one of the sites, Gelignite Creek, was there a difference in fire age across the boundary. At this site, the buttongrass moorland and wet-scrub boundary was last burnt 19 years before while the copse was last burnt 40 years before (i.e. in 1950, see Table 1). As can be seen in Table 2, there appears to be an increase in height and width of the outer-boundary with increasing time since fire.

Of these two factors, the increase in community height with increasing fire age would be expected as a result of the vegetation growing and maturing with time. In contrast, the increase in outer-boundary width with increasing fire age is more interesting since in all sites the outer-boundary was the same age as the surrounding buttongrass moorland (Table 2). This increase in outer-boundary width is probably the result of increased scrub (and to a lesser extent sedge) growth rates in that part of the buttongrass moorland which is immediately adjacent to the outer-boundary. This results in an apparent structural transformation of the buttongrass moorland into an outer-boundary community even though the floristic composition of the two community types was similar.

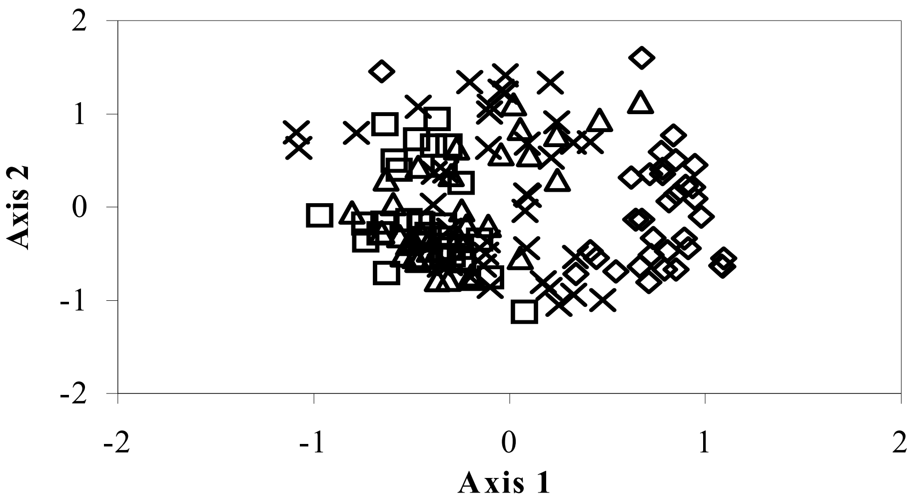
Soil variation by vegetation zone

There were major differences in soil type between the different vegetation communities (Table 3) which are probably attributable to variation in soil water-logging and the potential for gaseous exchange. There were no consistent differences in total soil depths and only small differences in pH. Organic content showed variation between the different community types (Table 4). The soil types in the buttongrass moorland communities typically consisted of a single P1 horizon of structureless black muck organic soil. In the outer-boundary zone the P1 horizon typically consisted of black intermediate organic soil over a black muck P2 horizon. In the inner-boundary the P1 horizon typically consisted of black fibrous organic soil over a black muck P2 horizon. The soil types in the wet-eucalypt forest communities were markedly different and consisted of shallow highly fibrous brown organic soil over mineral soil (see Table 3). All of the soils beneath the different vegetation communities were underlain by quartzite gravel.

Seedling growth dynamics under glasshouse conditions

Highly significant ($p < 0.001$ in all cases) differences in seedling number and height occurred at all of the scoring times between the different species and soil types (Fig. 4 and 5). These differences were mainly the result of slower growth rates on buttongrass moorland soils, faster growth rates on inner-boundary and wet-eucalypt forest soils and the requirement for stratification in *Leptospermum glaucescens* (Figure 5). However, even after the effects of the slower germination of *L. glaucescens* had been accounted for, differences were still evident between the different species in their responses to variation in soil type.

With the exception of *Leptospermum glaucescens*, after 147 days the species that normally dominate or sub-dominate in the wet-eucalypt forest and inner-boundary but not in the buttongrass moorland (i.e. *E. nitida* and *M. squarrosa*) showed significantly lower survival rates ($p < 0.05$ in all cases) than other species. By the same time (i.e. 147 days), on the wet-eucalypt forest soils, *L. nitidum* (the species that is normally co-dominant in buttongrass moorland) was significantly shorter ($p < 0.001$ in all cases) than the species that normally dominate the wet-scrub and/or wet-eucalypt forest, *E. nitida, L. scoparium* and/or *M. Squarrosa*. By the end of the experiment at 243 days, these differences in seedling number and growth rates were more pronounced. On buttongrass moorland soils there were significantly fewer seedlings of *E. nitida* than there were of *L. nitidum* seedlings ($p = 0.01$) while at the same time the seedlings of *L. nitidum* were significantly shorter than the seedlings of *E. nitida, L. scoparium* and *M. squarrosa* ($p < 0.05$ in all cases, Figures 4 and 5).



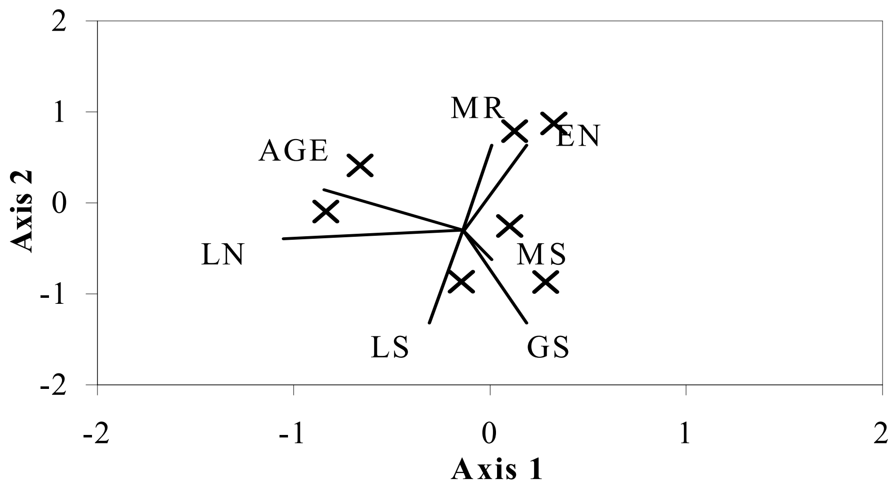
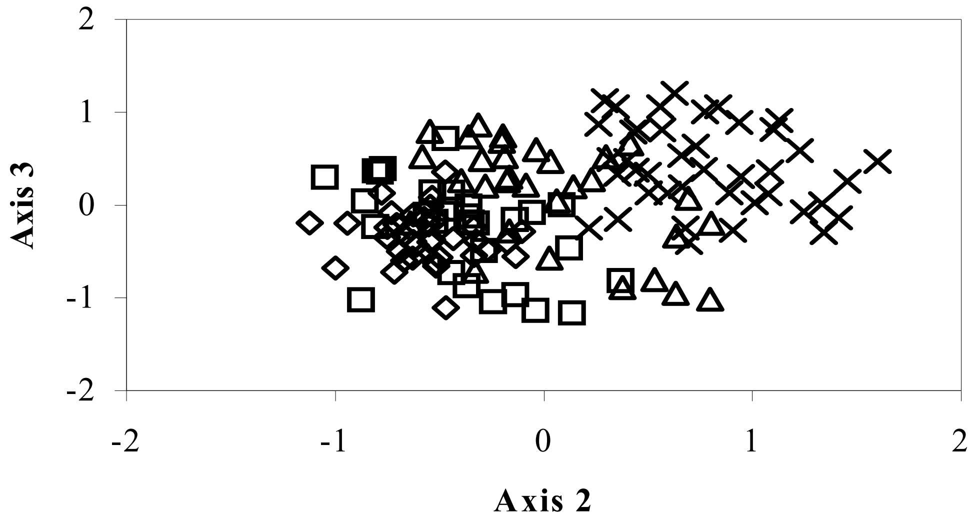


Figure 2: Ordination (axes 1 vs 2) with the upper chart showing the distribution of plots labelled by site location and lower chart showing direction of important species and environmental vectors.

◇ = Airstrip Rd, x = Sandfly Ck, Δ = Gelignite Ck, □ = Edgar; AGE = time since the last fire, EN = *Eucalyptus nitida*, MR = *Melaleuca squarrosa*, MS = *Melaleuca squamea*, LS = *Leptospermum scoparium*, LN = *Leptospermum nitidum*, GS = *G. Sphaerocephalus*)

Table 2: Variation in community fire age (years), number of plots sampled, height (m) and boundary width (m) at the different sites.

	Moorland			Outer-boundary				Inner-boundary				Copse		
Site	Age	Plots	Hgt	Age	Plots	Hgt	Width	Age	Plots	Hgt	Width	Age	Plots	Hgt
Airstrip Rd	2	14	0.6	2	4	0.8	2.0	2	6	1.2	3.0	2	10	15.0
Sandfly Ck	9	8	0.8	9	7	1.3	2.3	9	8	1.6	6.8	9	9	12.3
Gelignite Ck	19	8	0.6	19	6	1.3	3.0	19	9	2.7	5.5	40	11	11.1
Edgar	40	7	1.3	40	12	2.3	5.3	40	8	4.2	6.3	40	11	18.8



b.

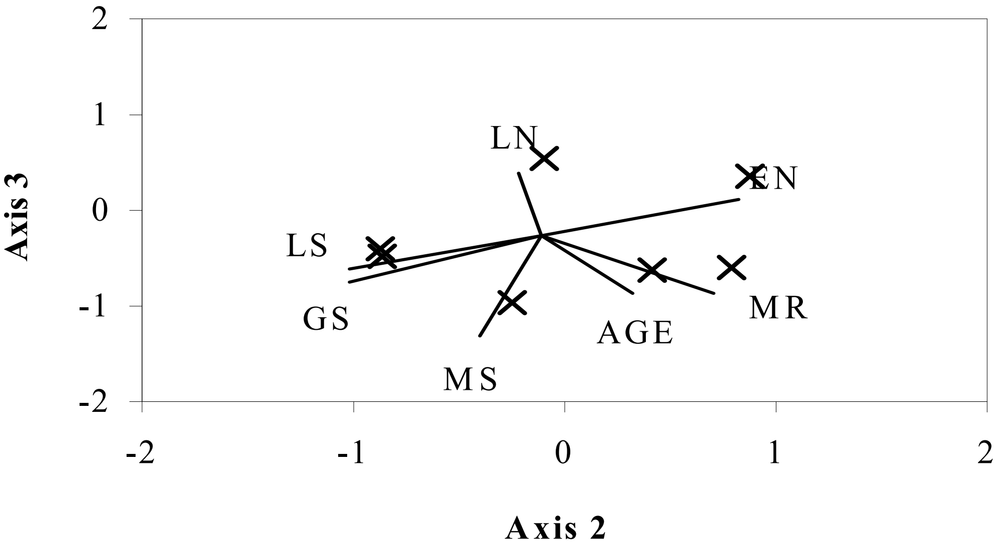


Figure 3: Ordination (axes 2 vs 3). Upper chart shows plots according to vegetation zone (as recognised in the field). Lower chart shows the direction of important species and environmental vectors.

◇ = moorland, x = outer-boundary, Δ = inner-boundary, □ = copse; AGE = time since the last fire, EN = *Eucalyptus nitida*, MR = *Melaleuca squarrosa*, MS = *Melaleuca squamea*, LS = *Leptospermum scoparium*, LN = *Leptospermum nitidum*, GS = *G. sphaerocephalus*.

Table 3: Soil types in the different vegetation types.

	P1		P2		
Community type	Soil type	Depth (cm)	Soil type	Depth (cm)	Subsoil depth (cm)
Moorland	black muck	20 to 40	not present	-	not present
Outer-boundary	black intermediate	10 to 15	black muck	10 to 15	5
Inner-boundary	black fibrous	10 to 15	black muck	10 to 15	10
Copse	brown fibrous	5 to 10	not present	-	25+

Note: all vegetation types were underlain by quartzite gravel.

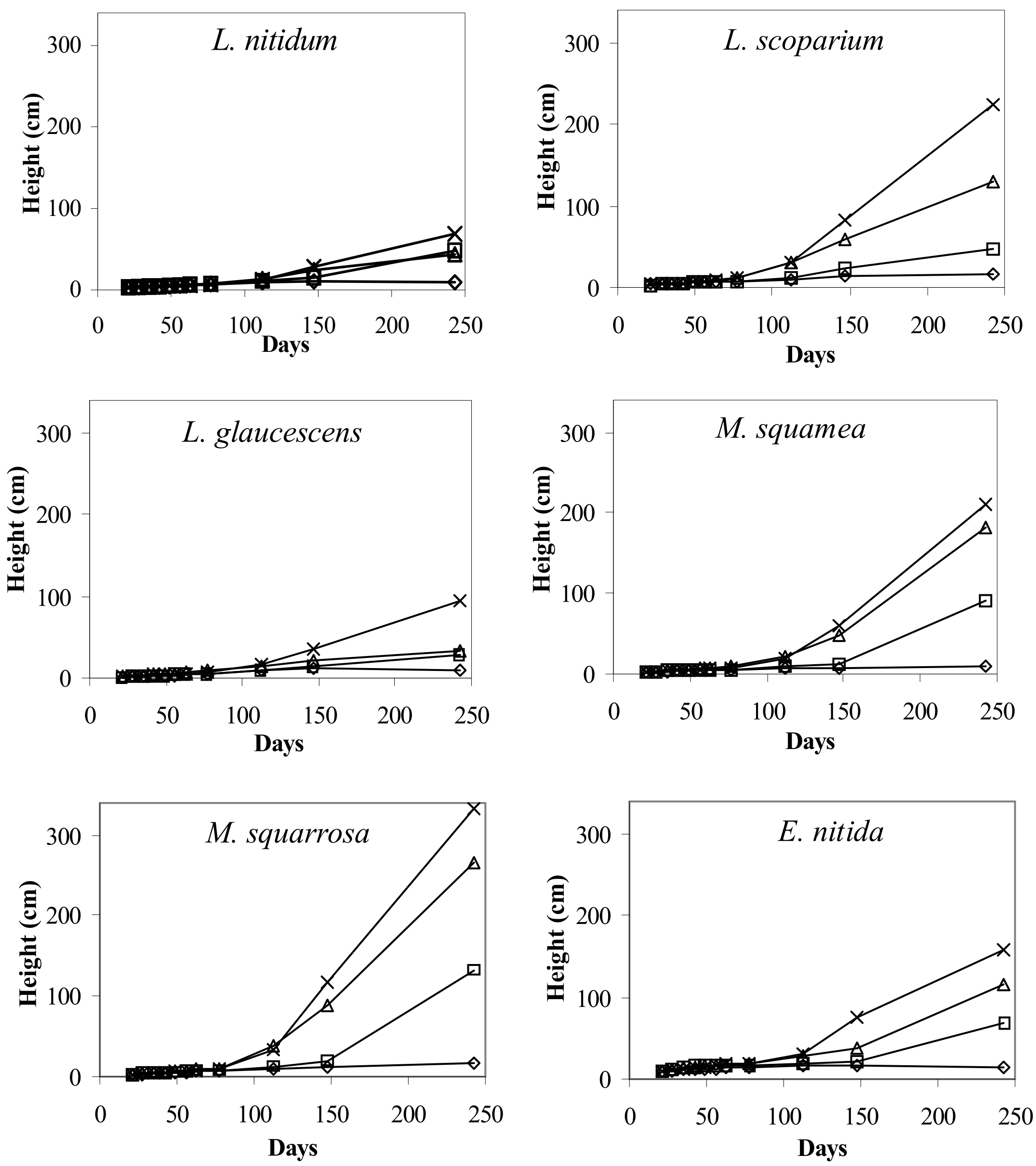


Figure 4: Seedling growth rates on different soil types under glasshouse conditions.
◊ = moorland soil, x = outer-boundary soil, Δ = inner-boundary soil, □ = copse soil.

Table 4: Average depth, pH and organic of content of soils by community zone.

Zone	Total soil depth (cm)			pH			P1 horizon organic content (%)		
	AVG	Sig diff	Level	AVG	Sig diff	Level	AVG	Sig diff	Level (zone)
Moorland (ML) -	37.2	a	nd	3.94	a	***(OB) **(IB)	48.7	a-	**(OB) *(IB)
Outer-boundary (OB)	34.6	a	nd	3.82	b	***(ML)	16.2	b	**(ML)
Inner-boundary (IB)	36.6	a	nd	3.80	b	**(ML)	23.7	b	*(ML)
Copse (C)	36.2	a	nd	4.04	ab	nd	28.6	ab	nd

Zones with significantly different soils do not share a common letter in column 'Sig diff'.
Significance 'Level': nd= no difference ($p > 0.1$); * = $p \leq 0.1$; ** = $p \leq 0.05$; *** = $p \leq 0.01$

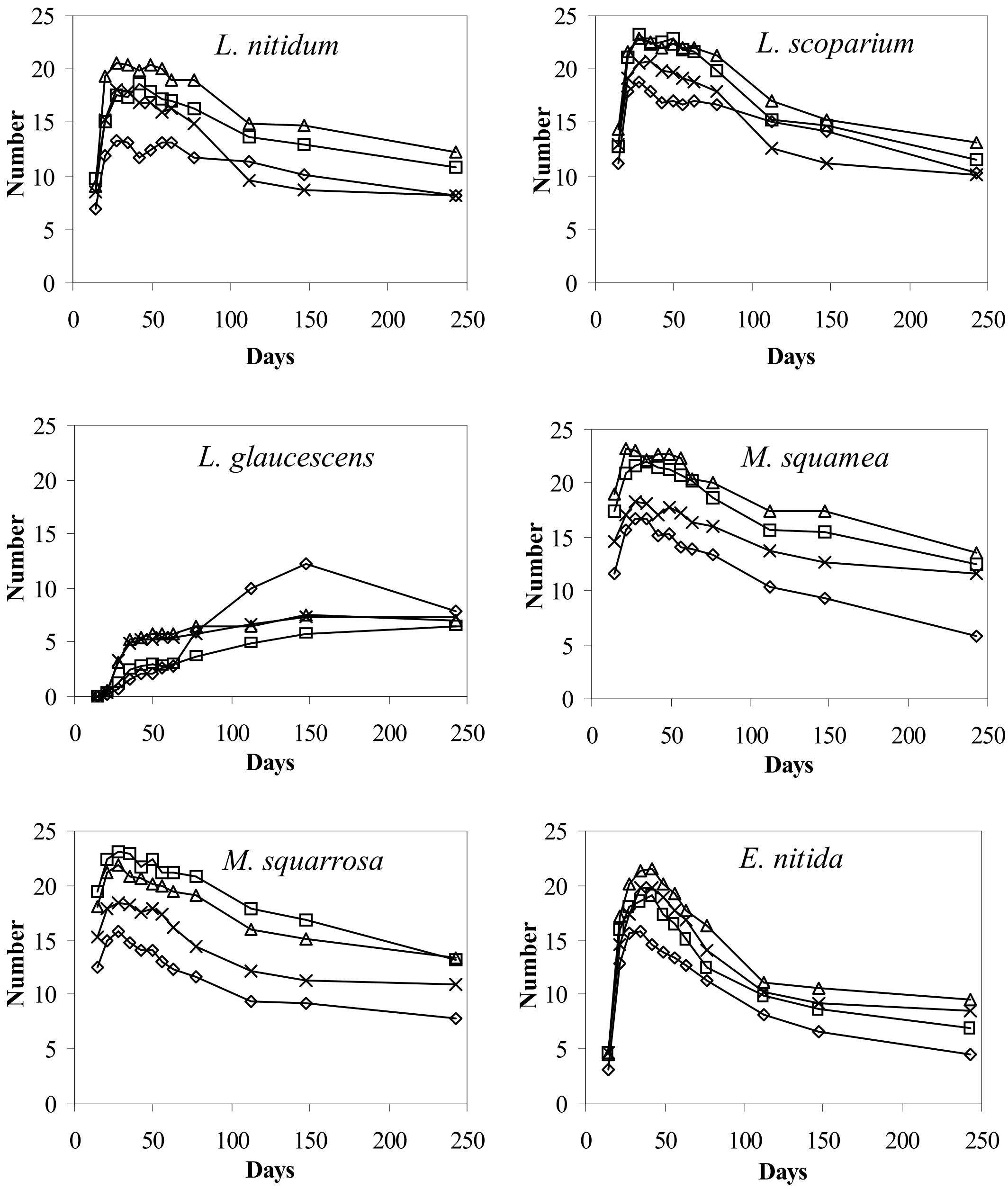


Figure 5. Seedling number on different soil types under glasshouse conditions.

◊ = moorland soil, x = outer-boundary soil, Δ = inner-boundary soil, □ = copse soil.

Discussion

The major findings of this study relate to the nature of the boundary between buttongrass moorland and wet-eucalypt forest and its dynamics in the absence of fire.

The boundary between buttongrass moorlands and wet-eucalypt forest can be divided into two distinct wet-scrub zones: an inner-boundary zone adjacent to the wet-eucalypt forest and an outer-boundary zone adjacent to the buttongrass moorland. The inner-boundary zone is typically dominated by *L. scoparium* and/or *M. squarrosa* while the outer-boundary zone is typically dominated by *L. nitidum*, *M. squamea* and/or *G. sphaerocephalus*.

In addition, with increasing time since fire in buttongrass moorlands that the part of the moorland which is immediately adjacent to the outer-boundary undergoes a structural transformation with the scrub species over-topping and out competing the sedge species. This results in a progressive transformation at the boundary interface giving the appearance that the boundary is moving out into the moorland.

A similar situation to this has also been recorded at Forest Lag near Melaleuca in southwestern Tasmania. In this situation, a series of permanent plots were set up in the early 1980s (see Brown & Podger 1982) and were resurveyed in 2000 (see Brown *et al.* 2002). Several of these plots were located on transects between buttongrass moorland and wet scrub and in these transects the width of the outer-boundary increased over the 20 years between sampling (Brown & Podger 1982, Brown *et al.* 2002).

In other long unburnt buttongrass moorlands in southwestern Tasmania similar changes to buttongrass moorland dynamics have been observed. In sites which have not been burnt since the very extensive fires of 1933/34 and 1897/98 the structure of the buttongrass moorland closely resembles the outer boundary. This is particularly the case for sites last burnt in the 1890s where the buttongrass moorland has structurally become a wet-scrub community whilst maintaining the floristics of buttongrass moorlands (i.e. dominated by *Leptospermum nitidum*, *Melaleuca squamea* and/or *Baeckea leptocaulis*). This situation can be clearly observed at the White Spur (grid reference 419900 5264500, AGD66/55) in southwestern Tasmania (JB Marsden-Smedley unpublished data).

The seedling germination and growth experiment conducted in this study also suggests that the different species have their best comparative growth rates and/or survivorship on the soil type on which they normally occur. This situation was also observed in the field. For example, species dispersal following fire across a boundary between buttongrass moorland and wet-eucalypt forest was measured in February 1990 at the Fourfoot Road near Geeveston in southeast Tasmania by Marsden-Smedley (1990). At this site, by four months following the fire, large numbers of eucalypt seedlings were observed to have germinated in all of the zones (i.e. buttongrass moorland, outer-boundary, inner-boundary and wet-eucalypt forest types), but none of these seedlings survived the winter except where they were under the wet-eucalypt forest canopy.

Although the work presented in this paper supports the proposition of Jackson (1968, 1978, see also Jackson & Brown 1999) that ecological drift will occur if changes in fire frequency occur, it strongly suggests that the time frames required for such ecological drift are considerably longer than those proposed by Jackson (1968). Jackson (1968) suggests that buttongrass moorlands will undergo ecological succession towards wet-scrub and wet-eucalypt forest when their average inter-fire periods are longer than about 25 years. The findings of this study, however, suggest that ecological drift will not occur in lowland low nutrient sites until the inter-fire period exceeds at least 75 years, with observational evidence from other similar sites suggesting that inter-fire periods of 100 to 150 years are required.

Recent fire regime modelling work performed in southwestern Tasmania also supports the proposition that although ecological drift has the potential to occur, Jackson's (1968) time frames are too short. King (2004a, 2004b) has developed a fire regime model of the region and her work suggests that Jackson's timeframes need to be at least doubled.

The reason for this discrepancy in the time required for ecological succession between this study and Jackson's (1968) work is probably the result of differences in the study sites used, their average fire ages and levels of soil fertility. Because of the difficult access to southwestern Tasmania in the early 1960s when W.D. Jackson collected his data, his study concentrated on sites in western and northwestern Tasmania (W.D. Jackson personal communication, 1990). Following the construction of the Gordon River and Scotts Peaks Roads in the late 1960s and early 1970s this situation changed, enabling easy access to central southwestern Tasmania. In addition, in the early 1960s the majority of western and southwestern Tasmania would have had fire ages of less than about 30 years (Marsden-Smedley 1998, Johnson & Marsden-Smedley 2001, J.B. Marsden-Smedley unpublished data). In contrast, in central northern and northwestern Tasmania ecological succession appears to be occurring at rates consistent with Jackson's (1968) hypothesis (Marsden-Smedley & Williams 1993, J.B. Marsden-Smedley unpublished data). The most probable explanation for these different successional rates between the southwestern Tasmania versus the rest of Tasmania relates to differences in soil fertility with the majority of southwestern Tasmania being of considerably lower fertility status than the rest of Tasmania (see Pemberton 1989, Grant *et al.* 1995, Jackson 1999a, 1999b).

In areas of low fertility in southwestern Tasmania it is proposed that a positive feedback loop occurs whereby the faster growth rates of *E. nitida*, *L. scoparium* and *M. squarrosa* in the wet-eucalypt forest and inner-boundary communities allows these species to overtop and out-compete the buttongrass moorland species *L. nitidum*, *M. squamea* and *G. sphaerocephalus*. In the buttongrass moorland, the reverse situation appears to be the case whereby the buttongrass moorland species have higher seedling survival rates than the wet-eucalypt forest and inner-boundary species. It is also highly probable that the effects of animals feeding primarily in the moorland and sheltering and defecating in the scrub and copse communities would result in nutrient transfer and hence enhance this process. The digging of burrows, primarily by wombats, would also be expected to result in enhanced soil aeration and lower levels of waterlogging.

The end result of these interactions is that under a regime of constant fire frequencies the dynamics of the different species will result in the location of the different zones (and hence the boundary) being stable. However, in the absence of fire, it appears that the plants in the buttongrass moorland immediately adjacent to the outer-boundary have enhanced growth rates resulting in the apparent outward movement of the outer-boundary. It also appears probable that the organic soils under the outer-boundary will be transformed by these enhanced growth and transpiration rates. This may result in enhanced soil drying and the oxidation of the muck organic soil underlying the buttongrass moorland, with the organic soil being replaced by better aerated and drained fibrous organic soil types. This changeover in organic soil type may be reflected in the lower soil organic contents in outer-boundary communities (Table 3). If the outer-boundary of a long unburnt site is subsequently burnt, then it is highly probable that the transformation in soil type would give inner-boundary and wet-eucalypt forest species the potential to invade and compete successfully with the outer-boundary and buttongrass moorland species resulting in the outward expansion of the inner-boundary and wet-eucalypt forest.

It is also worth noting that current research is suggesting that for the management of buttongrass moorland biodiversity the optimum fire regime is one of variable intensity, frequency and season with fires occurring at intervals of 20 - 30 years (Parks and Wildlife Service unpublished data). In addition, the application of prescribed fire is markedly harder and far more risky in long unburnt (i.e. older than about 20 years) compared to more recently burnt buttongrass moorlands. In old sites, fires burn with higher rates of spread, higher intensities and have a markedly lower probability of self extinguishing compared to younger sites resulting in a high risk of fire escapes (Marsden-Smedley *et al.* 1999).

If this description of the interactions between buttongrass moorland, wet-scrub and wet-eucalypt forest is correct then it has implications for the ecological management of southwest Tasmania. In this region, the benign neglect (see Brown 1996) that has been the dominant management practice over about the past 40 years has resulted in about half of the buttongrass moorland in southwestern Tasmania being in excess of 75 years of age (Marsden-Smedley 1998, Johnson & Marsden-Smedley 2001). If fire continues to be excluded from these buttongrass moorlands, then it is highly probable that within the next 25–50 years there will be a transition in the structure of the community with the result that there will be marked impacts on the ecology of buttongrass moorland communities.

In these buttongrass moorlands, an alternative management regime could be the re-introduction of a regime of variable frequency, intensity and size fires (see Marsden-Smedley and Kirkpatrick 2000). The techniques for reintroducing such a regime have been developed for Tasmanian buttongrass moorlands, and include methods for predicting fuel characteristics, fuel moistures, rates of fire spread, fire intensity and whether fires will sustain or self-extinguish (see Marsden-Smedley & Catchpole 1995a, 1995b, 2001, Marsden-Smedley *et al.* 1999, 2001).

Acknowledgements

In common with any study of this type, assistance was obtained from many people. In particular the authors would like to thank Jayne Balmer for analysing the data and Brad Potts, Gary Haig, Leigh Johnson, Jayne Balmer, Anne McEntee, Janet Morley, Mike Pemberton and Kristen Williams for assisting with the field and glasshouse work.

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Buttongrass
By Chris Cooper

Imagine if you will, if Baudin
Had navigated beyond the forested coast,
Into untracked moorland.

Images of muddy sails tacking
across vast paddocks of rosette tussock
would not have come to mind.

Nor would he have recognised
a Southern peatland unless sinking
his canvas trousers thigh deep into the *noir*.

He might have wondered
at the loosely audible arias
of grassy ground parrots.

He certainly would not have noticed
the *Parastacoides* crayfish browsing
on tight roots of buttongrass.

Or the footprints,
of the swamp *Antechinus* floating
like surface tension in the black mud.

But centuries later, we can imagine
his successors, taking a moment
to sit on the gravel bed of an alkaline pan.

Watching the sun drilling orange
into a horizon studded with the joy
and miles of an ancient ecology.

Buttongrass moorland vegetation recovery following fire

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This paper presents pre and post-burn comparisons of vegetation structure and floristics in Tasmanian buttongrass moorlands. The study compares the responses of moorland plant species at a fertile highland site in southern central Tasmania with a lowland, low fertility site in the southwest of the state. Results from the first five years of post-fire monitoring are presented.

At the high fertility, highland site, some significant changes from the pre-burn structure and floristics of the site are evident in the first few years post-fire. Several herb and graminoid species including grasses have increased in both frequency and cover and some previously absent herbaceous species have emerged in the post-fire vegetation.

In contrast at the low fertility site, there has been little change in the vegetation post-fire apart from a reduction in overall height. The species richness at the site has remained relatively similar to that pre-fire and is still depauperate compared with that at the high fertility site. The relative abundance of the species has also changed little.

Woody species at both sites in particular those which regenerate from seed have been slower to recover, suggesting that short the fire intervals are likely to reduce the relative importance of woody species in these communities. These results suggest that buttongrass moorland vegetation will respond to fire in markedly different ways depending of the characteristics of the site and of the pre-burn vegetation.

Introduction

The integral role of fire in the ecology of buttongrass is well documented (Gilbert 1959; Jackson 1968; Kirkpatrick 1977; Gellie 1980; Bowman and Jackson 1981; Brown and Podger 1982; Bowman *et al.* 1986; Marsden-Smedley 1998; Brown *et al.* 2002) and it is acknowledged that these ecosystems are well adapted to fire. Jarman *et al.* (1988a) provided observations about the relative fire sensitivity of a few species and also suggested possible successional relationships between some moorland communities and other vegetation types. Jarman *et al.* (1988b) analysed data from across range of buttongrass moorlands but were unable to show a relationship between fire history and vegetation due to confounding site factors such as fertility and drainage which appeared to more strongly influence community floristics and structure. They recommended that long-term monitoring sites be established to determine the effect of age and fire frequency on community composition. Gellie (1980) investigated the effects of fire on individual species and drew some useful conclusions regarding the regenerative strategies of different species and their ability to recover from fire. There is however very little published material documenting the structural and floristic changes that result when buttongrass moorland is burnt. This study aims to quantify some of those changes and to inform land managers as to the likely impacts of fire on buttongrass moorlands and in particular the impacts on specific life forms and on individual species.

This paper presents the results of six years of post-fire monitoring at two different sites dominated by buttongrass (*Gymnoschoenus sphaerocephalus*). One site is a relatively fertile (dolerite parent material) montane (~780 m) eastern moorland site at King William Creek in central Tasmania and the other is a low fertility (quartzitic parent material) lowland (~320m) site at Airstrip Road in the southwest of the state. According to the classification of Jarman *et al.* (1988a) the vegetation at King William Creek is 'eastern moorland' that is intermediate between 'layered eastern moor' and 'common highland sedgey' while the Airstrip Rd site supports 'blanket moor' which is consistent with the definition of the 'standard peat' community.

It was postulated that, at either site, fire would tend to disadvantage shrubs and woody species, in particular those which regenerate from seed, and that other life forms such as grasses, forbs and sedges would be encouraged, due to both reduced competition for resources and by virtue of their ability to quickly regenerate. It was anticipated that low fertility might further disadvantage some species because limited nutrients would further restrict their ability to quickly re-establish post-fire. It was also anticipated that there would be an increase in diversity at one or both sites post-fire both as a result of decreased competitive exclusion and of stimulation of the soil stored seedbank by heat and/or smoke.

Methods

At both sites ninety-six relocatable 2x2 metre plots were established. These were divided among six 50x50m treatment areas. Within each treatment area the plots were laid out in a grid pattern, with sixteen plots in each (four rows of four). Three of the treatment areas were designated as control areas and the remaining three were designated as treatment (burn) areas. Data collection involved estimating the percentage cover of each species in each plot. These data were then averaged for each treatment area to give an average cover for each species across each area. Each site was surveyed once prior to the burning of the treatment areas and then resurveyed at regular intervals post burning. The King William Creek Site was burnt in Autumn 1999 and Airstrip Rd was burnt in Autumn 2001. Both burns were of low to moderate intensity.

Results and discussion

The post-fire responses of the major life forms at the two sites are illustrated in figures 1–9, and are summarised in Table 1. At both sites around 80% of species were observed to regenerate from surviving root stock with the remainder regenerating from seed. This is consistent with pervious observations of regeneration after low intensity fires (Gellie 1980).

There was a 10% increase in species richness on the burnt plots at King William Creek (from an average of 19.2 species per grid to 21.2 species per grid) three years following the fire. Species richness on the burnt plots was declining back to the pre-fire levels after six years but was still slightly above pre-fire levels (Fig. 1). Species richness at Airstrip Road was not noticeably influenced by fire (Fig. 2), possibly because the fertility at the site reduced the ability of new species to colonise the area. It is also possible that because the Airstrip Road site had not been burnt for 32 years prior to the beginning of this study the soil seedbank lacked viable the propagules of opportunistic fire stimulated species.

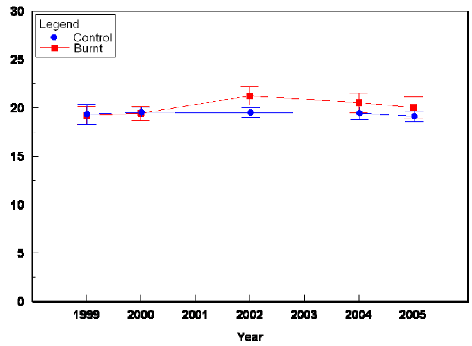

Figure 1: Mean Species Richness for burnt and unburnt grids at King William Creek.

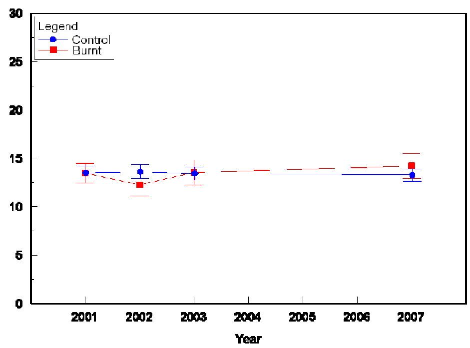

Figure 2: Mean Species Richness for burnt and unburnt grids at Air Strip Road.

Immediately post-fire at both sites there was a flush of herbaceous species but this response was much more pronounced at King William

Creek. At both sites sedges and woody shrubs were slower to recover than the herbaceous species, but by six years post-fire at King William Ck the shrubs and sedges had both recovered to their pre-burn covers. At Airstrip Road neither of these life forms had fully recovered.

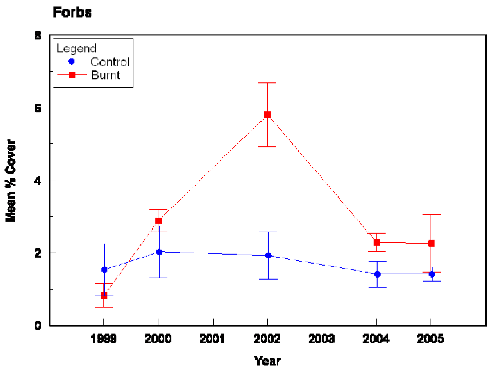

Figure 3: Mean percentage cover of forbs at King William Creek over time.

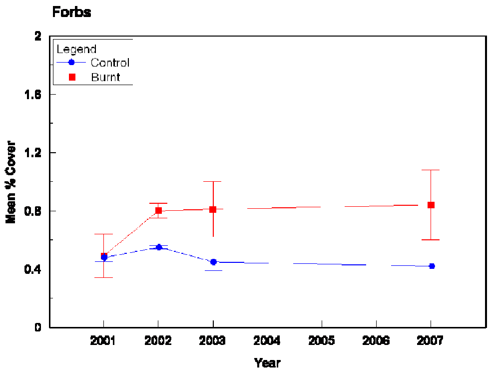

Figure 4: Mean percentage cover of forbs at Air Strip Road over time.

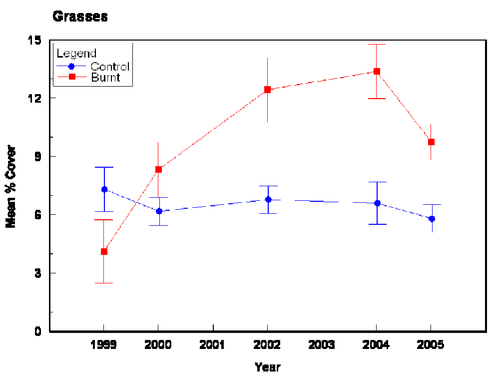

Figure 5: Mean percentage cover of grasses at King William Creek over time.

At the less fertile site, indications are that the post-fire recovery of the sedges and shrubs in particular are being limited by fertility. At the more fertile King William Creek site all life forms have returned (after six years) to levels approximating those that existed prior to the site being burnt, but the sedges and shrubs are still to recover completely at Airstrip Road.

In the initial post-fire period, forbs and grasses were encouraged by fire as a result of their ability to quickly take advantage of the increased space, nutrients and sunlight (reduced canopy shading) in the wake of burning. At the more fertile King William Creek site the cover of forbs increased by over 600 % three years post-fire (Fig. 3) while at the Airstrip Road the increase was a more modest 63% (Fig. 4). The cover of grasses at King William Creek increased by over 200% in the same period (Fig. 5). No grasses were recorded at Airstrip Road either before or after burning. The most recent visits in 2004 and 2005 have seen a decline in both the grasses and forbs at King William Creek probably as a result of competitive exclusion as the sedges and shrubs reassert their dominance. At Airstrip Road the small post-fire increase in forbs is still being maintained six years on which probably reflects the relatively slow resurgence of the sedges and shrubs and the consequent lack of competitive exclusion at that site.

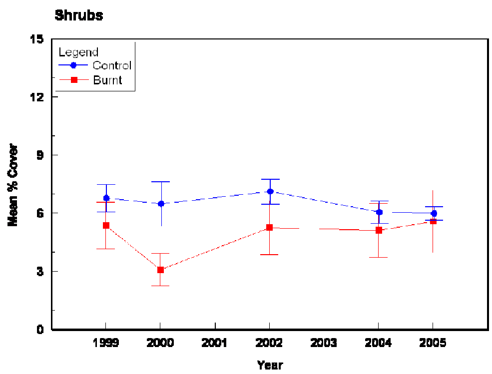

Figure 6: Mean percentage cover of shrubs at King William Creek over time.

At the Airstrip Road site shrubs have been slower to recover and six years post-fire they have still only regained about half of their pre burn cover. A major element of the shrub cover at Airstrip Road is/was *Melaleuca squamea,* a species which is killed by fire and recovers exclusively from seed. As it takes considerably longer for shrubs regenerating from seed to develop compared with species which resprout, it is not surprising that the shrubs at Airstrip road have been slow to return to their pre-burn cover. Bauera rubioides which has been observed to resprout fairly commonly at other sites also seemed to primarily recover from seed at Airstrip Road and consequently it too has recovered relatively slowly. Sprengelia incarnata is an obligate seed regenerator at both sites and it has recovered well, reaching levels of cover similar to pre burn levels within three years at King William Creek in less than six years at Airstrip Road.

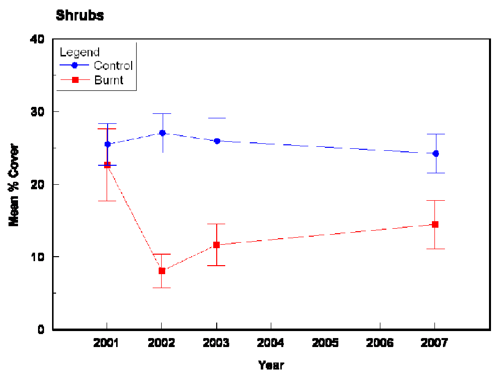

Figure 7: Mean percentage cover of shrubs at Air Strip Road over time.

The slow recovery of shrubs regenerating from seed has significant management implications for how fire is managed in these types of communities. Our observations in the field suggest that the juvenile period of *Melaleuca squamea* is between 4 to 7 years. Gellie (1980) made similar observations suggesting a juvenile period of 3 to 6 years. Many individuals at Airstrip Road are yet to flower six years after fire, suggesting that a sustained fire frequency at the site of less than six years could eliminate *M. squamea* from the site. The recovery strategies of the species in buttongrass communities and their primary and secondary juvenile periods are critical to effective fire management. This would apply in particular to sites similar to Airstrip Road where fertility is low. At these sites species are not only required to regenerate from seed but to do so in a nutrient poor substrate which will tend to make them grow more slowly and possibly mature later. As a consequence less fertile sites are likely to require longer inter-fire intervals if the more vulnerable elements of the vegetation are to be maintained.

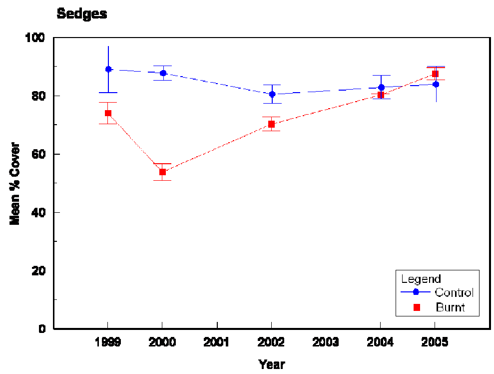

Figure 8: Mean percentage cover of sedges at King William Creek over time.

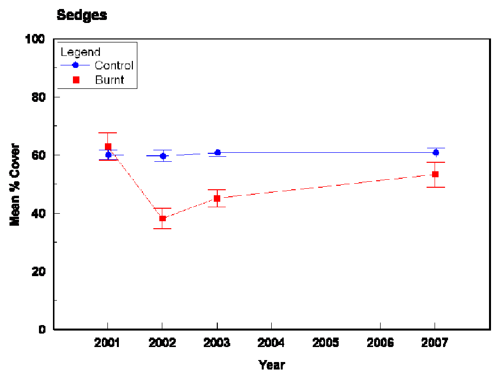

Figure 9: Mean percentage cover of sedges at Air Strip Road over time.

Table 1: Summary of results six years post-fire

KWC:

- high altitude & fertility
- dense at 12 yrs
- large flush of forbs
- large flush of grasses
- shrubs recovered
- sedges recovered
- initial increase in species richness

ASR:

- low altitude & fertility
- relatively open at 32yrs
- small increase in forbs
- no grasses
- shrubs not yet recovered
- sedges not yet recovered
- species richness steady

Acknowledgments

Esme Atkinson, Richard Barnes, Kerry Bridle, Mick Ilowski, Karen Johnson, Josie Kelman, Michael Lichon, Colin McCoull, Tim Rudman, Cassie Strain and Jennie Whinam, all assisted in data collection. The experimental design and plot establishment was initiated by Michael Driessen. Jennie Whinam assisted with soil data collection and provided valuable comments on the manuscript. Glen McPherson provided statistical advice and conducted some analyses on species cover data. Allison Laboratories, Hobart analysed the soil samples. The Commonwealth Government contributed funding through both the Tasmanian Wilderness World Heritage Area Program and Natural Heritage Trust (1999).

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The Animal Within

By James Charlton

Exhausted
by Frenchmans Cap,
I ease my body
between buttongrass clumps
onto moorland dampness.

My breath
grows steadier
One thought
spawns another
with less alacrity.

The animal within
tastes silence
beyond thought,
stillness
beyond form.

Cubed droppings on softly abrasive
astelia alpina.
Tiny sundews' amber
stickiness.

I sense earth's joys,
more piquant
being transient,
ease myself down
onto moorland dampness.

Avifaunal habitat use and potential availability of arthropod prey resources in relation to post-fire succession of buttongrass moorlands in the Tasmanian Wilderness World Heritage Area

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Fire management has become an increasingly critical issue in areas of high conservation value such as the buttongrass moorlands in the Tasmanian Wilderness World Heritage Area (TWWHA). This study compares habitat use by the buttongrass moorland avifauna between three habitats (i.e. matrix, riparian and edge) at different stages of post-fire succession, and relates that use to the availability of potential arthropod prey. Given that time since last fire and site productivity are the primary variables in the models currently used to predict fire behaviour and guide prescribed burning and wildfire control operations in buttongrass moorlands, a replicated space-for-time study was established that included two fire-age chronosequences of different productivity levels. Locations included blanket moorlands near Lake Pedder (10 sites; 2–54 years post-fire; low productivity) and eastern moorlands near Lake St Clair (12 sites; 1–31 years post-fire; moderate productivity). Data on the use of habitats by birds were collected during the course of distance sampling surveys conducted at all sites. The potential availability of arthropod prey resources was measured using vacuum sampling approximately one year after the habitat use surveys and was limited to matrix and riparian habitats at 11 sites at Lake St Clair (<1–32 years post-fire).

Observations of habitat use in the study area demonstrated significantly non-random selection of habitats at both locations by the resident guild (incl. Southern Emu-wren, *Stipiturus malachurus*; Striated Fieldwren, *Calamanthus fuliginosus*; and Ground Parrot, *Pezoporus wallicus*) and non-resident guild (incl. 18 spp.). These patterns were related to differences in habitat type and availability, guild membership, and their interactions. In all cases, the relative selection probabilities were greater than expected for riparian and edge habitats when compared to the matrix. At Lake St Clair, the availability of different habitats, fire ages, and their interactions were significantly related to habitat use by the avifauna. In contrast, fire age was not significantly related to habitat use at Lake Pedder. Overall, both guilds were more likely to select riparian habitat at Lake St Clair when compared to Lake Pedder. Differences between locations may be attributed to the greater structural and floristic diversity across fire ages provided by riparian habitats at Lake St Clair compared to the sedge-dominated matrix of these eastern moorlands, whereas such differences between habitats are less pronounced in the scrub-dominated blanket moorlands at Lake Pedder.

Mean abundance (no. m-2) of potential arthropod prey (9 orders) vacuum sampled in eastern moorlands at Lake St Clair was significantly higher in riparian than in matrix habitats across fire ages, while the difference in mean energy content (J m-2) was non-significant between habitats, but was significantly reduced in recently burnt sites when compared to medium-aged sites (i.e. <1 vs. 16 years post-fire). Thus, the availability of prey resources as indicated by both mean abundance and mean energy content was higher in riparian habitats and in medium aged sites (5–16 years post-fire), while prey resources appeared to be very limited in recently burnt sites (<1 year post-fire) and also less available in older sites (32 years post-fire). These findings indicate that the arthropod community exhibited a post-fire reduction and recovery pattern, concomitant

with that of the vegetation community. At the ordinal level, there were significant differences in energy contributions of the arthropod community between matrix and riparian habitats, and between fire ages, indicating that both factors may influence the availability of arthropod prey resources in eastern moorlands. Hemiptera, Diptera, and Araneae were ubiquitous in the study area and dominated the community in relation to total abundance and energy content vacuum sampled, as well as similarities in mean energy content within each habitat and fire age category. Although published data on the dietary preferences of moorland insectivorous birds are limited, these findings suggest that Hemiptera, Diptera, and Araneae constitute the main source of potential arthropod prey in eastern moorlands.

This study has identified for the first time that the use, and hence value, of riparian zones for the resident and non-resident bird species in both low and moderate productivity Tasmanian moorlands is disproportionately high compared to their extent in the moorland landscape (i.e. <5% of study area). In the case of moorlands of moderate productivity at Lake St Clair, selection for these habitats by insectivorous birds reflects the greater availability of potential arthropod prey across fire ages. These results suggest that future research is warranted and should focus on quantifying the foraging behaviour and dietary preferences of moorland residents (particularly the insectivorous Southern Emu-wren and Striated Fieldwren), obtaining additional food resource data, and obtaining demographic data to provide a fitness framework within which to consider these findings and to develop a better understanding of the underlying processes.

Since additional research is needed to better understand the dynamics of avian habitat use and prey resources in buttongrass moorlands, it is difficult to make any definitive management recommendations at this time. However, the findings of this study indicate that preservation of moorland riparian habitats is important since they provide the avifauna, and particularly the resident species, with critical resources including adequate cover, food, perches, and nesting sites, and may also provide better protection from predators. These habitats also serve as important post-fire refugia and possibly dispersal corridors, particularly in the case of extensive prescribed burns or wildfires that may displace large portions of the resident populations. Effects of prescribed burning operations on riparian zones have not been explicitly addressed to date, whereas woodland and forest edges are often used as secure boundaries and are not extensively burnt under normal conditions. The typical aim of hazard-reduction burning is to reduce 70% of fuels over 70% of the moorland area. Depending on the prescription, fuel characteristics, and weather conditions, riparian areas may constitute part of this unburnt area. However, riparian areas can be extensively burnt by the primary fire, or may be hand-torched by fire crews if they remain unburnt after the initial fire front has passed. Since burning such small patches of habitat is unlikely to appreciably contribute to hazard-reduction aims, it is recommended that fire crews are informed of the importance of preserving unburnt patches to provide post-fire refugia for the fauna. It is also recommended that, to the extent practicable, explicit prescriptions are developed to ensure portions of riparian habitats and other emergent vegetation (e.g. scrub copses) remain unburnt within each site to provide adequate availability of suitable habitat and arthropod prey resources, and to sustain the natural dynamics of habitat use of the avifauna across the landscape and over time. These recommendations are consistent with those for other cover-dependent heathland bird species, for which post-fire persistence and re-occupancy are facilitated by a mosaic of unburnt and burnt vegetation within and across territories.

A critical component of conserving the moorland avifauna will be conducting monitoring of the resident populations. Ideally, surveys should be conducted throughout the TWWHA, but at the very least in areas that are the focus of fire management activities, such as within the Lyell Highway corridor near

Lake St Clair. Minimal effort would be required to train staff to identify the resident species by sight or sound. During the course of this study it only took approximately 20 minutes on average to establish presence of the resident species during point and line transect surveys. Accordingly, only short and informal point or walking surveys would be required to establish presence of the resident species. Such surveys would require minimal resources and could primarily be conducted during the course of other management activities in moorlands (e.g. during pre- and post-burn inspections). However, in order to obtain reliable results for the Ground Parrot, surveys would need to be conducted during their calling-flight sessions at dawn or dusk. If presence-absence surveys become standard practice, these data could be used to determine whether fire management activities are leading to adverse effects, such as local extinctions of the resident species, and be used to modify strategies accordingly within an adaptive management framework.

Buttongrass- and what lies beneath

by Alex Dudley

A tussock,
with five nodding, gnarled heads.
Droplets of water hang from yellow beards
raised high above a green grass skirt that reaches down to the black peaty soil;
heads dance and nod
to the tune of a cold wind with the promise of snow.
But beneath the yellow green skirt
the dry grass waits;
Dark and deadly amongst her sheltering fronds
a tiger snake sleeps coiled and still
neighbour to a restless ball of fur
which chews tunnels out of sight beneath the dancing tussocks.
The broad-toothed mouse knows the burrowing crayfish
and the sinuous slender bluetongue
and she fears a warm tiger snake.
but she knows her cold neighbour poses no present danger,
and in the secure dark,
chews thoughtfully on the white base of a blade of grass.
Her world is this field of buttongrass,
her running tunnels,
the smell of peaty earth.
She doesn't know the nodding heads above are conspiring
- waiting for fire,
for the liberation of undead seeds.

Fire suppression in buttongrass moorlands in western Tasmania

Adrian Pyrke

Manager Fire Operations, Parks & Wildlife Service, Hobart, TAS

From 2003 to 2007 a combined area of approximately 120,000 hectares of buttongrass moorland was burnt by six major wildfires that started from lightning strikes in western Tasmanian reserves (Table 1). In a very real sense these fires were largely uncontrollable shortly after ignition. The extent of peat fires once the fire spread had slowed or stopped was well beyond any level of suppression resources available in Tasmania. The fires were all extinguished by rain, in some cases several months after ignition.

A relatively small area of fire sensitive vegetation (e.g. rainforest) was burnt by these fires; and the probability of larger rainforest fires occurring is low. These lightning fires did, however, contribute to the gradual decline in the area of long-unburnt rainforest. Larger fires in rainforest or other fire sensitive vegetation with long-term negative impact may occur in the future.

This paper aims to emphasise the limited options available to land managers with regards to fire suppression in western Tasmania and the considerable expense of even small suppression operations. The reality of the fire suppression situation highlights the significance of other fire management options such as prescribed burning.

Mt Frankland-Donaldson fire statistics

- ignited by lightning 15 Nov 2003
- 78,000 ha burnt in total
- 34 days suppression work
- $1,000,000 in costs (not including normal salaries)

Table 1: Major lightning fires in Tasmania 2003 – 2007 (areas estimated from aerial boundary mapping).

Yearof fire	Location	Area burnt
2003	Mt Frankland Donaldson	78,000 ha
2006	Mt Castor	3,150 ha
2006	Elliott Bay	1,295 ha
2007	Reynolds Ck	25,240 ha
2007	Terminal Pk	900 ha
2007	Cracroft	13,070 ha

Figure 1 summarises the development of the Mt Frankland-Donaldson fire. The lightest pink is the fire at day 3 (Fig.1). By day 4 (mid-pink) the fire had already reached the coast. Day 4 and 5 (deeper pinks) the weather was benign and the boundary only moved slowly north and south. On day 6 the wind direction changed to north-westerly and the fire did a major run to the south and east.

On day 8, the only active fire suppression was some back-burning in the northern part of the region.

By Day 12 the fire had reached the forest boundaries. Day 12 to 16 the fire sat and smouldered, expanding only into areas of unburnt moorland.

Day 17 the fire spotted over the Pieman River (dark red).

Day 19 the final boundary was nearly reached, but the fire continued to burn the organo-sols in the scrub and forest margins for the following few months. There was approximately 110 km of smouldering fire boundary that could have run (escaped) at any time over the summer.

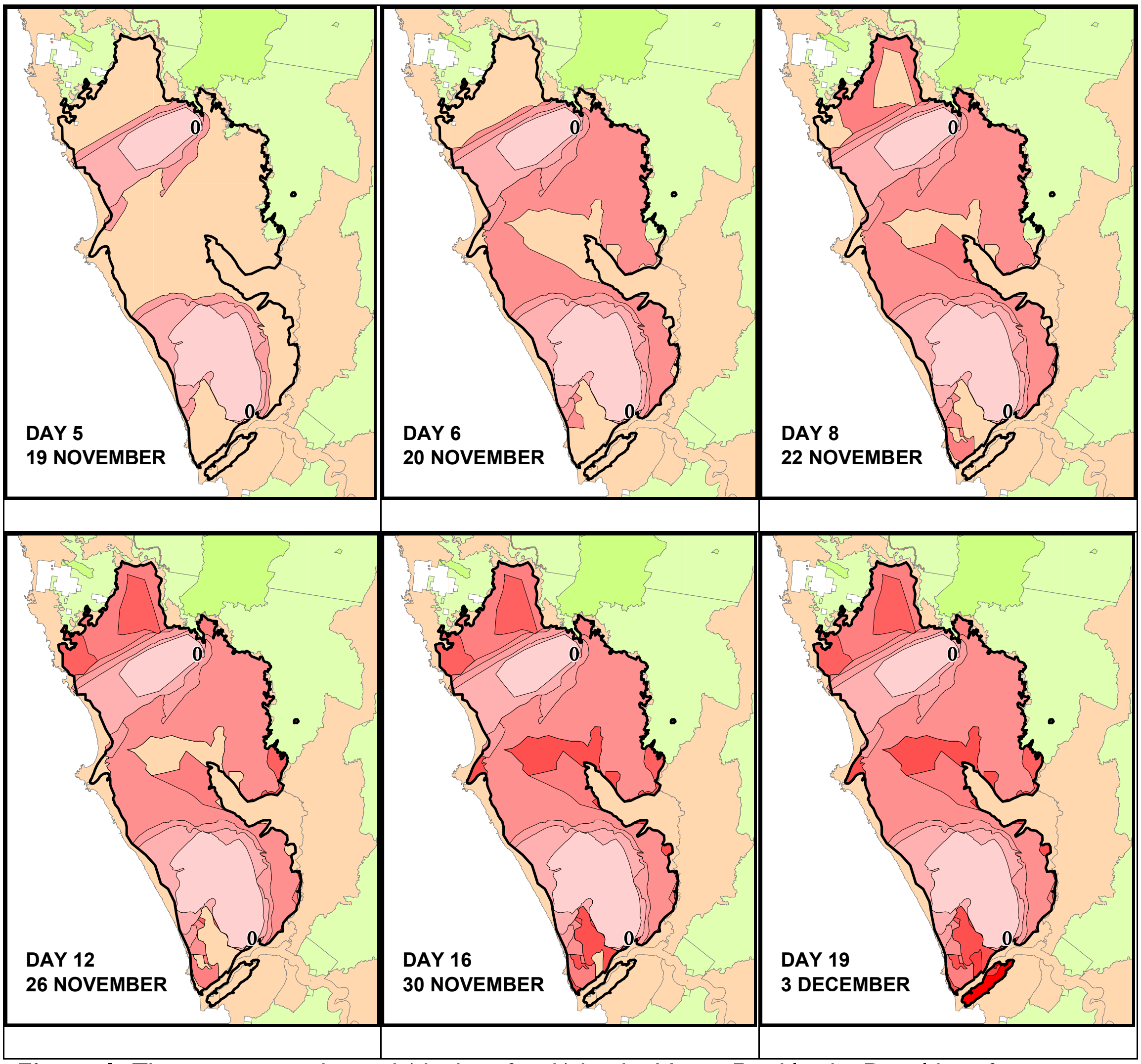

Figure 1: The extent areas burned (shades of pink) by the Mount Frankland – Donaldson fires on days 5,6,8,12,16 and 19. Reported ignition points are shown as '0'. Pale-brown areas are conservation land tenures managed by the PWS. Areas shaded in deeper lime-green are forest reserves managed by Forestry Tasmania. Pale-green areas are state forest managed by Forestry Tasmania.

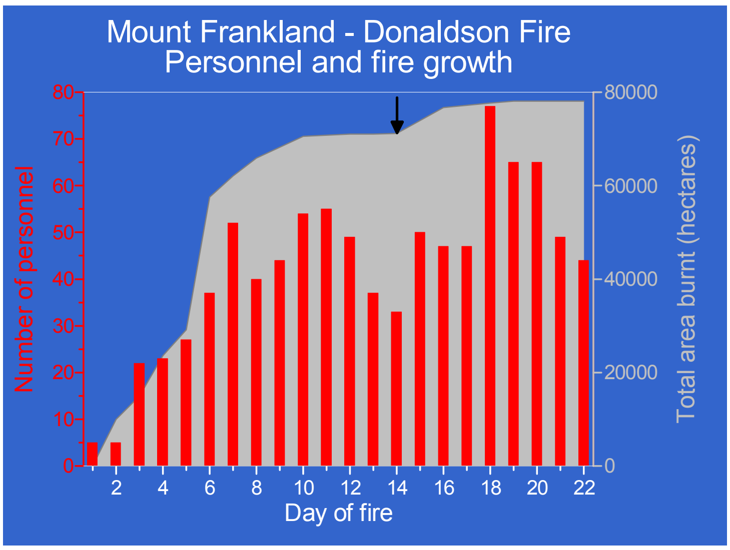

Figure 2: Data on the fire size and number of personnel involved in fire suppression work.

There was no time at which anything could be done to prevent the Mt Frankland-Donaldson fire spreading to the extent it did. The limit of spread was determined by the time of year and the fact that the forests were still too wet to burn. Very little prescribed burning had been undertaken in the region for several years so that there was very little capacity to slow the run of fires in buttongrass. Suppression action (Fig. 2) was limited to back burning at the far northern end and direct attach on small targeted sections of the fire perimeter.

Mourning Joy on the Moorlands

By Naomi Lawrence

Dear Brother, when you were dying, memories came flooding back
Of all those times we shared when we were children growing up.
Our Dad, he loved adventure, our mum loved us all to go
And on excursions we all went, through fog and frost and snow, right off the beaten track.
Across the plain, we'd bump and hump along the gravel road
The grassy buttoned bobbing plain, our flag ship
The sign we'd left and when we returned, that we were close to home
And when fog was thick as soup, at times a lumbering bulk would loom, a curdling in our blood.
There were cattle on the moorlands, strange as that may seem
They were mustered up at summers start and down at summers end.
I guess they must have missed some when they drove them down the hill
Leaving luckless strays on that moor to counter winters bitter chill and of greener pastures dream
One brilliant sun drenched winters morn as we bumped across the plain
We came upon the button grass all cloaked in frosty glow
Wafts and waves of light split rainbows shimmered all about like sparks
Burning deep that gleaming scene upon our child free hearts, till joy had no restrain.
We clambered out and off we set across the bobbing moor that day
Till down a ridge we dropped where we found some hidden caves
All edged with dripping stillness hanging dagger like and shining there
We knocked them down and yelled "en guarde" waving icicles in the air, like pirates hard at play
Brother you died, too young it seemed, I'm so sad you had to go
Maybe now your spirit plays upon the breeze across the golden moor
And over the wild hills where we found adventure all around
Where the echo of your voice did once resound and you fished in summers glow
But more likely your spirit breath searches all the rivers round the valley green, high and low
For that fishing spot, so that when next time you come to Earthly life,
You will at last catch the biggest trout, 'sinker' free this time
(though you never thought fair cheating was a crime)
and win that competition you were so keen to, all those years ago.

Workshop 1: Lessons from history

Question: What lessons can we learn from history? What are the problems facing sustainable moorland ecosystem management?

Workshop Leaders: Kerry Bridle and Geoff Hope

There was general agreement that glacial and periglacial processes reduced the extent of forest and created problems for seedling regeneration and tree survival, this would have been exacerbated by Aboriginal burning when people arrived.

Rather than being restricted to lowland river systems the Tasmanian rainforest species may have occurred as dwarf trees and shrubs on the subalpine slopes (perhaps as higher than 500 m altitude). *Athrotaxis*, *Eucryphia*, *Nothofagus* and *Phyllocladus* can all survive as shrubs at the treeline. High altitude relict patches of trees appear to have survived at Mt Read and Mt McCutcheon.

Bird dispersal enabled a rapid expansion of celery-top pine dominated rainforest after the ice disappeared 16 ka BP and been followed by a slower expansion of *Nothofagus*.

There was a great deal of discussion about evidence for and against the expansion of rainforest. Alternative interpretations of pollen cores from several sites were discussed. It was generally concluded that rainforest expansion did not occur in a systematic upward migration but rather in all directions from relict pockets as conditions ameliorated. The extent of rainforest expansion was not agreed upon since pollen transport and relative quantities vary over-time as vegetation changes.

It was generally agreed that burning by Aborigines in combination with the late glacial climate conditions led to an expansion of buttongrass moorland ecosystem and prevented rainforest expanding to their climatic potential. Buttongrass moorland might therefore be viewed as a cultural landscape.

Peter McIntosh's sand dune and erosion studies provide supporting evidence that there was an increase in burning activities around 35000 to 40,000 years ago, a time that corresponds with the arrival of people.

It is unclear when the earliest records of *Gymnoshoenus* appear in the palaeo records, but as a significant vegetation formation it appears to have become important in Tasmania for the first time late last-glacial.[2] Michael Fletcher's work has showed that buttongrass moorland floristic assemblages were not static but changed in response to changing climate throughout the Holocene.

Some people in the group were concerned by their belief that senior managers/ministers are risk adverse and are more concerned about escapes from planned fires than in preventing potential future wildfires.

Evidence was accepted by some members of the group that without regular burning it is more likely that we will have more frequent and severe landscape-scale fires.

There was a general agreement that some form of burning regime is necessary to maintain this ecosystem since history shows us that it has always been associated with a frequent fire regime.

Diaries provide some historical evidence that Aborigines were using and burning buttongrass moorland at the time of European arrival. However there was a consensus that

[2] Mike Macphail (2010) cites 3.5 ka BP as the earliest known macrofossil evidence for *Gymnoschoenus sphaerocephalus* in southern Tasmania. In an email dated 3 March 2008 he communicated that the earliest dates that he has for *Gymnoschoenus*/*Baumea* type pollen are from ~2.3 Ma (mid Pliocene) from the Yallalie (meteor crater) sequence in southwest Western Australia published in *Dodson, J.R., Macphail, M.K.* (2004) 'Palynological evidence for aridity events and vegetation change during the Middle Pliocene, a warm period in Southwestern Australia', *Global and Planetary Change*, 41, pp. 285-307.

we don't know what the past burning practices were and that we don't know what a suitable regime should be now.

There was a general agreement that fire management burning should aim to preserve values and the buttongrass moorland–forest mosaic. One way of doing this may be by strip or mosaic patch burning as proposed by Jon Marsden-Smedley.

Monitoring of the results and feeding back information learnt from monitoring back into management decision making was seen as essential. Managers need to budget for monitoring and the assessment of monitoring information ensuring that management is adjusted accordingly. Dave Bowman suggested that the same model medical practitioners use to ensure that their new treatment methods are effective should be adopted.

Information flow was considered critical, to try and inform the public of the value and need to protect values with management burning.

Editor's note: An edited transcript of the entire workshop discussion has been filed in the DPIPWE electronic records system and is freely available upon request.

Workshop 2: How much do we know?

Question: How much do we really know, and what do we still need to learn?

Workshop Leaders: Ian Houshold and Mick Brown

Review of values

At the time of the workshop (July 2007) the WHA values were being reviewed and the review process was discussed. It was noted that the review of values will be required periodically as more discoveries are made within the WHA and the rest of the reserve system. Formal re-listing of areas is not needed in order to protect these newly discovered values. All values should be being managed according to their importance regardless of whether or not they were listed as one of the reasons for reservation or WHA listing. As our knowledge and understanding of an area changes it will be necessary to periodically reassess the significance of the reserved values so as to appropriately manage them.

Processes of organic accumulation and decline in buttongrass soils.

The workshop discussed the fact that we do not know very much about the accumulation rate or decline of organic matter in buttongrass moorlands soils in Tasmania or how management affects these processes. This was considered a critical question to answer in order to develop appropriate fire management protocols. Geomorphic and biological systems are affected by these processes. To answer this question we can make use of the palaeo environmental research or we could use process studies- that is measure peat accumulation directly (but this would take decades). It is worth setting up process studies to complement palaeo research and more importantly assist in answering questions around how changes in management can influence the rates of accumulation.

Moorland ecosystem fire dynamics

Fire history buttongrass moorlands is only partially known and more work is required. In particular further studies of the:

- pre-European fire dynamics using palaeo-environmental analysis
- effects of burning intensity and duration (resonance time) of wildfires and management burns on the distribution of buttongrass moorlands, moorland boundaries and succession processes and
- interactions of soil moisture and shallow ground water dynamics on the combustion of organic matter during fires of differing intensity and duration.

Inventory of values and scale of studies

Continue inventory of natural values (biodiversity and geodiversity) and natural processes at a variety of scales. There was a discussion about the issue that managers probably prefer studies to be undertaken at macro-scale- habitat and landscape scale rather than the micro-scale. But it is important that all scales are studies to get a complete understanding of the ecosystem. The management of individual components of the ecosystem is required to ensure that elements of the system are not lost (eg threatened species) and that key processes continue to process. This brings us back to the issue of significance and so we need defensible ways of assessing the significance of things. How important is geodiversity compared with biodiversity. How important are lichens compared to landscape soil interactions- all those questions we haven't addressed properly.

Regionalisation of buttongrass moorland ecosystems

Regionalisation of buttongrass moorlands is needed for management purposes, since not all buttongrass moorlands are alike, they include a ranger of floristic types that reflect underlying differences in soils, topography, climate etc. Broad existing regions include georegions and bioregions; These regional areas of buttongrass moorland may provide a better focus for management-oriented research questions.

Importance of the arts and story-telling to communicate values

Communicating information through the arts and telling stories using poetry, prose and oral presentations may prove more effective at communicating ideas and values of buttongrass moorlands than conventional scientific writing and interpretation. These might include Aboriginal and post-European stories about the landscape and buttongrass moorland values and might be used to convey ideas about the cultural landscape.

Incorporation of outside knowledge

Research is not just conducted within the TWWHA and it is often not appropriate to undertake potentially destructive research within this area. The results of research undertaken in buttongrass moorland or similar ecosystems elsewhere in Tasmania, Australia and internationally should be regularly reviewed for its application to buttongrass moorland management in Tasmania and the TWWHA.

Biophysical models of ecosystem function

Development and use of biophysical models to understand environmental processes and how management can influence the ecosystem is of key importance to better management. One such model is the firescape model (King 2007). Need to determine and define the key parameters for each model. Various models may be needed to explain the ecosystem functioning at the various scales of management and operation.

Workshop 3: What is impacting on moorlands?

Question: What is impacting on moorlands and how can we manage these processes better?

Workshop Leaders: Mike Driessen & Grant

Introduction

The group identified processes that have the potential to negatively impact on buttongrass moorland. The table below lists threats in rank order (5 high, 1 low). There was only time to discuss four of these topics.

Threat	Rank
Climate change	5
Phytophthora cinnamomi & other plant pathogens	5
Faunal pests, especially foxes	5
Inappropriate fire management regime (inappropriate for the protection of values)	5
Chytrid fungus, Devil Facial Tumour Disease & other animal diseases	4
Walking & other recreational impacts	4
Promotion, i.e. encouraging visitation & use leading to impacts	3
Inappropriate developments, e.g. wind farms, future large dams, etc.	2–3+
Agricultural conversion (in northwest)	2
Mining & mineral exploration, e.g. tin mining at Melaleuca	2
Tourism developments, e.g. developments and associated sewage dispersal in moorlands	2
Weeds	1–2
Erosion due to runoff from old disturbances, e.g. former roads & tracks	1–2
Altered hydrology due to road construction (for example)	1
Impacts on visitors experience (e.g., noise from overflights)	NA

Animal pests (fox)[3]

The current approach to fox management is aimed at preventing their establishment in Tasmania.

The best approach is to manage the problem before it gets into buttongrass moorlands.

It is essential that this issue maintains a high profile (foxes in Tasmania, risks etc).

Chytrid[4]

Educate widely re. the problem and issues.

Need to develop a higher profile for the problem and issues.

Research target audience and appropriate message.

Ongoing monitoring of impacts and spread.

Adopt a similar management strategy to that developed for *Phytophthora cinnamomi* management.

Use the *Phytophthora cinnamomi* management 'rules' in the interim.

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[3] DPIPWE publications on fox eradication can be located at: http://www.dpiw.tas.gov.au/inter.nsf/WebPages/LBUN-5JNW5U?open#Publications

[4] Since the workshop the 'Tasmanian *Chytrid* management plan' was produced by the Biodiversity Conservation branch, (2010). It is available as a PDF file at http://www.dpiw.tas.gov.au/inter.nsf/Publications/LJEM-8887EH?open

Climate Change[5]

The precise impact on and response of buttongrass moorlands to climate change is unknown.

Better climate modelling is needed in order to better assess the risks to moorlands and constrain the range of potential response options.

A climate change risk assessment should be undertaken.

Further work is required to determine if button grass moorlands have a carbon sink value.

What can we do –

- Education & promotion of the issue.
- Identify refugia and protect them.
- Undertake fire suppression, e.g. to protect refugia.
- Alter fire management to mitigate climate change impacts (more or less firing depending on ecosystem responses).
- Ex-situ conservation of species.
- Consider radical measures such as genetic modification or species translocations.

[5] Since the workshop DPIPWE commissioned the report 'Monitoring the Impact of Climate Change on the Flora and Vegetation Values of the Tasmanian Wilderness World Heritage Area: A Review' (Brown 2010) This unpublished report is available as a PDF file at http://www.dpiw.tas.gov.au/inter.nsf/Attachments/LJEM-8AE3AT?open.
DPIPWE also reviewed the vulnerability of the natural environment (including buttongrass moorland) to climate change in the report:
DPIPWE, Resource Management and Conservation Division (2010). Vulnerability of Tasmania's Natural Environment to Climate Change: An Overview. Unpublished report. Department of Primary Industries, Parks, Water and Environment, Hobart. This is available at http://www.dpiw.tas.gov.au/inter.nsf/WebPages/DRAR-88P8CY?open

Phytophthora cinnamomi (root rot)[6]

Protect protectable areas.

Clarify and refine what controls are effective in managing spread by human vectors (recognising can't control other vectors).

Clarify and refine what eradication methods are effective for small infestations.

Undertake further research into use/potential of phosphite.

Adopt a risk management approach.

More public education about measures people can take to reduce risk of spread.

[6] A non-statutory Parks and Wildlife Service plan 'Tasmanian Wilderness World Heritage Area *Phytophthora cinnamomi* Management Plan 2008-2017' is the basis of current management in that area.

State-wide management advice for *P. cinnamomi* management is provided in several reports including:

Rudman (2005) Interim *Phytophthora cinnamomi* management guidelines. *Nature Conservation Report 05/7*. DPIWE, Hobart. Available at http://www.stors.tas.gov.au/au-7-0037-00182;

Parks and Wildlife Service (2003*) The Tasmanian reserve management code of practice.* Parks and Wildlife Service Tasmania, Department of Tourism, Parks Heritage and the Arts, Hobart.

Schahinger, R.B., Rudman, T.R. and Wardlaw, T. (2003) Conservation of Tasmanian plant species and communities threatened by Phytophthora cinnamomi. *Nature Conservation Report 03/3.* DPIWE, Hobart.

Workshop 4: General fire management

Workshop Leader: Malcolm Gill

Values to be considered in developing fire management strategies:

- Risks of increased rate of spread of *Phytophthora cinnamomi* as a consequence of fires at inappropriate frequency/intensity/resonance time.
- Risks of losing organic matter in soils, and soil erosion from inappropriate fire frequency/intensity/resonance time.
- Risks of burning fire sensitive vegetation (alpine vegetation and rainforests) from inappropriate fire management.
- Managing fire in the face of conflicting management objectives, for example in the TWWHA there is a desire to allow natural processes to operate, but this may be at odds with protecting particular values either by actively managing fire using prescribed burning or fire suppression.
- Land systems processes operating over long time scales

Aspects of fire management that need to be considered in fire management planning

- Scale of fires— the size and scale of fires
- What is achievable within practical constraints of financial resources?
- What would happen if we did nothing?
- Climate change and the implication of unknown changes in weather patterns for the future
- Fire management situations within the World Heritage Area where natural ecological processes are supposed to be able to run their natural course.
- Protecting economic assets outside reserve areas at the boundary of reserves
- Fire management processes need to be considered as a whole at all scales and not dealt with as a component of single elements.
- Protecting fire sensitive assets in vegetation surrounding/adjoining buttongrass moorlands
- Defining biodiversity objectives of fire management across space and time (short term gains and losses compared with longer term objectives).
- Management strategy needs to be interactive, enabling research and on-ground outcomes to feed into next phase of management on a continuous iterative basis
- Important of taking necessary risks that are clearly spelt out within management plans

Knowledge

- Important to recognise that there is already a solid knowledge base. This needs to be reviewed regularly to ensure that what is known already is not overlooked but is fully built into research strategies and management.
- What new research areas do we need to invest in?
- What existing research areas can be added to efficaciously?
- How can be develop a more collaborative approach to research and knowledge sharing?
- What can we realistically achieve? What research is essential?
- What is the rate of climate change and what impact is this having on values and fire management?
- Fire ecology processes need to be researched holistically across the range of scales of interactions
- research endpoints need to be defined
- interactive feedback between information and management
- determine thresholds of impact of management in terms of the risk of the action being irreversible for a particular period of time

Communication:

- Need to communicate the importance (values) of buttongrass moorlands and the public reserve system to the general public. The use of 'Locked Up' in relation to reserves is often employed to persuade people that reserves are not available to them. This negative view of public reserves needs to be challenged.

- Need to communicate the importance of fire and fire management to the general public— to communicate its positive creative force to counteract the negative and destructive image the public have of fire.
- Educate the community about what they can realistically expect from managers and fire management
- Researchers and managers need to communicate more effectively (researchers need to be provided with up-to-date management outcomes, and vice versa)
- Need to develop structures, mechanisms and technologies that enhance collaboration and communication.
- Communication of risks

Social /Political

- The influence of a social environment in which litigation and personal attacks are rife and the inhibiting of managers from taking responsible actions

Editor's note: An edited transcript of the entire workshop discussion has been filed in the DPIPWE electronic records system and is freely available upon request.

Workshop 5: Microcosm or landscape?

Question: Management for microcosm or landscape?

Workshop Leader: Peter Clarke

This group was led by Peter Clarke and looked at the issue of management and scale. We agreed that there is a continuum from the ecosystem landscape-scale to the micro-scale. Perhaps the most important issue is that there are multi-directional feedbacks between processes that operate at a range of different scales. Understanding and taking this into account is important for both research and management. Questions like — What scale do *Sphagnum* bogs fit in the continuum? Are they catchment or landscape? Superimposed on this issue is the added complexity of climate, and climate change, and fire. All of which operate at a range of scales. And then there is the need to look at the links between processes.

The next level is about how to interlink the knowledge from those different facets at the micro and medium-medium scale up into the landscape scale. Knowledge gaps make this difficult and the considering the scale of issues is important in efficiently directing choices. We (DPIPWE) use this approach in a limited way through the Directed Wildlife Research Funds, but we need to be more proactive about how we identify information gaps and how we research them. The example provided by our workshop group, was the relationship between biodiversity (in its largest sense) on a continuum of scales, with soils and water catchments. Biodiversity doesn't occur without soils and water in the landscape, so we should be able to place the management and research of biodiversity into that context. Biodiversity, soils and catchments are different things, but of course they are also linked.

The group also agreed that there is a need to consider values. A lot is already known about the values of buttongrass moorlands (but typically this knowledge is determined by single disciplinary research approach).

A holistic approach in which the inter-relationships between 'geo', 'cultural' and 'biological' processes is essential for a more complete understanding and better management. We need to work/talk together to determine how processes intermesh. Eric Colhoun used the term 'biogeocenosis'. With a better understanding (through group discussions) of the processes, how they link and the mechanisms driving ecosystem dynamics it should be possible to determine what aspects of the ecosystem are at the greatest risk. From a common understanding of both the greatest values and risks an agenda and priorities for research and management agenda can be determined. However it is important that the recommendations need to relate to clear objectives/ desired outcomes. To achieve this there is a need for layers of priorities which acknowledge the linkages.

Our group agreed that we all know that there are things that have to be done, but what we need to do next is agree on the objectives and the priorities.

The group came up with two priorities requiring investigation:

- What is the relationship between geological substrates and organic deposits and how and where do organosols develop and how do they fit into that landscape continuum?
- What are the hydrological properties of organosols; under what conditions can these soils be burnt by fire?

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Workshop 6: Balancing values and protection needs

Question: How do we balance values and protection needs?

Workshop Leader: Malcolm Gill

Within this workshop, Malcolm Gill suggested that the group list the major stakeholder groups (excluding scientists) relevant to the buttongrass moorland fire management program. He then asked that we consider the issues that might impact on these stakeholder groups and how they would react to various fire scenarios. Table 1 reflects the generalised suggestions made by the group.

The group first looked at values and determined that the values vary depending on which perspective you look at them from. In Tasmania, our Minister is one person who should value buttongrass moorlands. And the values we believe the Minister will see in buttongrass moorlands are: the potential for jobs through tourism, the clean green reputation of Tasmania, and votes if there's no problems with the management of buttongrass moorlands in Tasmania. If there's a problem with the management, then that could affect the votes, which may affect the way it's managed in turn. On top of that we have the Federal Minister, who is concerned about WHA management and Australia's international reputation (to a certain degree) which to some degree is impacted by the way we manage buttongrass moorlands. If we can effectively manage them, then the Minister can be on the high horse at international conventions and say "we're doing a great job, you'd better lift your act" to other countries. The group also considered that the Federal Minister might be interested in the cost of implementation of fuel-reduction burning program for management of buttongrass moorlands.

The group considered the interests of the local green groups — they have an interest and they will recognise different values in buttongrass moorlands, or the WHA in general. They may value wilderness, biodiversity, conservation and the intrinsic value of having natural areas. We believe that they'd be looking at minimal intervention (this is a generalisation, since there's a whole range of green group opinions, this is just one we've thought of). They'd also have concerns about the non-reserved buttongrass areas in Tasmania.

Now land managers (especially Parks and Forestry Tasmania), values are different again. Managers are likely to see buttongrass moorlands from the stewardship point of view. They need to fit in with legislation in the management of the moorlands and, to a degree, product management from a tourism point of view as well. For them as land managers, they need to make sure to manage buttongrass moorland so that it is seen to be of value to the Tasmanian people and not a threat.

The Aboriginal community might value the maintenance of the landscape, potential for jobs to assist in the fire-management of buttongrass moorlands. They are likely to value and care for moorlands for their sense of place.

The perspective of the Tasmanian suburban local, is likely to cover a very wide range of values. In general we thought that they may see buttongrass as a recreational asset, often long-term recreational uses, such as camping: so campfires, 4WD use, quad bikes, etc. And there's probably resentment from this group about the locking up of moorlands in reserves which has restricted their access to using buttongrass moorlands in these ways. Certain sectors of the community probably feel that buttongrass has been 'locked up'.

Commercial developers, tourism, miners, may see moorlands as a financial asset or risk to assets. They would wish to ensure that they can make money out of — or they'd be looking for protection of their facilities.

The group also looked at fire management issues —unplanned fires and suppression, versus a pro-active fire management program from each of the stake holders perspective.

The State Minister might potentially view an unplanned fire as a problem, as it might be suggested that the wildfire was a result of a lack of responsible management (insufficient prescribed burning). Alternatively wildfires may be an opportunity to be seen shaking fire-fighter's hands and so provide a public profile. A fire program may be pro-active and a positive vote winner, but there's also smoke issues for management, a big issue in Tasmania.

Federal Minister might consider that large unplanned fires are an international issue and therefore view these negatively. A fuel-reduction program could be considered pro-active.

Green groups might view a large fire as a disaster for all the things that they value. We believe they'd be cautiously supportive of a fuel-reduction management program.

Land managers (e.g. Parks and Forestry staff) were considered to generally accept that fires happen, so are generally supportive of fuel-reduction burning. We believe that the Aboriginal community might have a whole range of opinions but are likely to support an active fire-management program. Local Tasmanians might consider large wildfires interesting TV viewing, but would have a big concern of unplanned fires affecting them directly. In general they'd probably be supportive of fuel-reduction burning, but there's concern with smoke and access issues. Developers would be concerned that unplanned fires in summer might have a really big impact on tourism numbers. They are likely to be cautiously supportive of a fuel-reduction burning program because it has the potential to reduce risks for them.

Table 1: List of some buttongrass moorland stakeholder groups, the issues that may concern them and their possible reactions to planned and unplanned fire events.

Group	**Issues** about buttongrass mgt that stakeholder group may recognise as important	**Reaction to:** Unplanned wildfire event	**Reaction to:** prescription burning
Aboriginal Community	• Cultural landscape maintenance • Sense of place • Caring for land • Employment opportunities through P&WS other govt employment programs	? likely to vary widely between individuals..	Supportive May want to be consulted May want to participate
Local suburban households	• Availability for recreational use (e.g. camping, fishing, walking, 4WDing resentment of no campfires) • resentment about restriction to access or activities permitted	interest in TV coverage concern about impacts short term concern if directly impacted by reduced access/ amenity	? likely to vary widely between individuals. may be concerned about impact of smoke emissions
Tasmanian Minister	• Employment opportunities • Votes • Tourism opportunity • Clean green reputation • Minimising cost of mgt	Problem if blamed for being responsible Positive if it shows govt capable of conducting suppression operations	Seen to be pro-active Concern about negative image of smoke
Australian Govt Minister for WHA & environment	• International reputation & status • Cost of mgt	International standing may be diminished	Seen to be pro-active
Local Green Group	• Wilderness • Biodiversity & other intrinsic values • Minimal intervention • Conservation of non-reserved buttongrass	Disaster Likely to Consider wildfire as detrimental to intrinsic values	Cautiously supportive
Commercial developer (e.g. tourism or mining)	• Ability to capitalise on resource as a financial asset • [jobs] • Protection of facilities & activities	Economic impacts/risk to assets or business	Supportive of minimising risk to assets/business
Land Managers (e.g. Parks & Forestry Tas)	• Land stewardship • Product mgt • Implementing/enforcing legislation	Accept inevitability of wildfires Large impact on staff routines but accept this as part of the job	Cautiously supportive

Workshop 7: Prescribed fire regimes

Question: What prescribed fire regimes do we want for buttongrass moorlands?

Workshop Leader: Adrian Pyrke

The group discussed the question 'what prescribed fire regimes do we want for buttongrass moorlands?' To try and operationalise this into fire management, in the planning sense, it is necessary to known the ideal minimum fire intervals, maximum fire intervals, size, where, percentage of the landscape, when, why and how fires should burn in buttongrass moorlands. There is still a lot we don't know.

Clear direction is needed to determine how much of the landscape should be burnt and why. The first step to achieve this is to divide the buttongrass vegetation into fire management zones, each with specific management objectives. The zoning should be across the entire landscape. Following the mapping of assets, it will be necessary to work out, which require protection. The group identified a need for at least three zone categories. The first was a risk and asset protection zone, which is about protecting assets which are both cultural and natural. The second was a special ecological values zone which would include key habitat for the orange-bellied parrot. The third zone was the rest of the buttongrass landscape, the broad area. But within that it was quite clear that we need to recognise the diversity of that landscape by identifying special management units. These would represent the diverse range of geomorphic and bio-diversity.

The concept of an experimental prescribed burning (program) was also raised. The group recognised that such an experiment would need to be big and it appeared that there was a general consensus that the group was talking about western Tasmania. That's big!

1. Asset Protection Zones – where the fuels are reduced to manage risk to specific assets. A lot of work is still needed to identify and map the assets (including cultural, economic and natural assets) across the entire WHA.

On the basis of those assets, the size or areas needed to allocate to the asset protection zones, and the percentage of area that would be required to protect those assets would then need to be determined. On that basis the group started looking at some of the prescriptions for the asset-protection zones. For example, how wide should they be? It was considered that in general this zone might have the following management characteristics:

- A width of 1–2 km, or where 'natural' boundaries are more logical it may be narrower or wider (e.g. mixed forest, rainforest, wet scrub, roads)
- clear objectives identified for fuel load management fuel load management, related to productivity, which will define a minimum fire interval threshold
- some change, both positive and negative will be accepted and expected within these zones due to higher fire frequencies [discussion highlighted that high frequency burning may cause positive changes to biodiversity and geodiversity as well as negative changes]
- performance based burning, for example, targeted fuel reduction objectives (which may mean burning an area twice in one year because we must achieve fuel management objectives for risk mitigation).

The group didn't have time to discuss the special ecological values zone (e.g. Orange-bellied parrot habitat areas) but it did begin a discussion about zone three, the rest of the half a million hectares that are out there.

It was agreed that we really need to divide the buttongrass landscape in western Tasmania into management units to recognise geomorphic and floristic variation. These management units would be identified on the basis of the uniqueness in terms of the vegetation type and/or geomorphic values, and productivity, slopes and flats. There should not be a single fire regime across that whole landscape but instead it would be necessary to determine fire regime parameters for each management unit.

The group did debate technological ignition methods. Aerial approach (helicopter and incendiary devices) to burning was viewed as the most cost effective. But others considered that ground ignition (people with drip torches) might be a more intimate burning treatment to the landscape and might provide something emulating the traditional Aboriginal pattern of burning but no consensus was arrived at.

There was seen to be a need to clearly define the objectives of all prescribed-burning in this zoning area [zone three]. Objectives may include the creation/maintenance of a mosaic of vegetation fire-ages so that biodiversity and other intrinsic values (e.g. peats and soils) are also maintained. Some units in the area would be identified as areas for fire exclusion. The group did get to the point of agreeing that we should be maintaining areas of old-growth moorland and identifying areas of these that won't be burnt at all. In fact the group suggested that it might be necessary to have some asset-protection zones around some of those old-growth moorlands to maintain them as old-growth moorlands.

The objectives for prescribed burning of 'Broad Area' Zones are as follows:

- maintain a mosaic of post-fire ages
- not lose intrinsic values
- maintain some areas unburnt (perhaps use Asset Protection Zone burning around some old growth buttongrass areas!)

Monitoring and evaluation is essential at the scale of the 'experiment' (i.e. across the entire area where prescribed burning is occurring). The experimental area was identified as being all of western Tasmania. This gives due recognition to the view that all prescribed burning is experimental because the outcomes in terms of ecological and risk mitigation objectives cannot be known for certain at this time. In other words, all prescribed burning is a component of adaptive management and must be continuously evaluated.

The group could have discussed this topic for a much longer time. Many issues were not fully resolved and more detail could have been developed with more time. Nevertheless the group felt that it had been a productive discussion.

Final summing up

By Malcolm Wells

Chairman of the World Heritage Area Consultative Committee

(Transcript of presentation by Malcolm Wells, edited for readability.)

I'm not a scientist, and I think the previous workshop reports in some ways pulls together at least the scientific parts of the conference, but I'm particularly interested in process and I'm also interested in the process going forwards. So I'll make some comments about that. I thought that the title of the next conference might be 'Managing the golden fire-sedge moorlands — cultural artefact or natural ecosystem?' and take it on from there — because in some ways it encapsulates, for me, some of the debate that has occurred here over two afternoons.

I think the other theme for me, is that, despite the science, the real task here is managing complexity and managing values. How successful you are going to be in terms of getting your messages across, really gets back to how successful you can be in managing that complexity and the values under-pinning that complexity. And I'd better declare that I've got a few values, like everybody else, and what I say will largely depend on those. I think that two principles in particular are relevant.

The first is that, because our environment is so complex and inter-dependent, communication and the public relations system are particularly important. It's great to get the whole system in the room when you're making decisions, like you have at this conference, instead of only having bits of the system (which so often happens). It's interesting that in the workshop that Malcolm Gill facilitated [Workshop 4], a couple of comments were made about "Well, we can do all this stuff, but so what! If nobody knows about it because we can't communicate it, it [a lot of the effort] is wasted!" And I'm not just talking to people like yourselves that might read the *Australian Natural* whatever-it-is *Journal*. I'm talking about other stakeholders that ought to have some understanding of these values to input into their management. We started to talk about it up here with Ministers and others [pointing to butcher's paper summary from workshop 6], because they represent a wide range of other stakeholders.

The second principle that I've got is that all decisions we make, even so-called scientific decisions, are value based. Now some people won't agree with that I know, but that's what I believe. Many years ago I read a couple of books that I guess influenced me: Schumacher was one, the other book was by a guy called Gary Zukav who wrote a book called "The Dancing Wu Li Masters", which was all about explaining to plebs like me what quantum physics is all about, and it was a real eye-opener. If you haven't read it, I encourage you to. It's hard to get but you can still get it from most of the web book providers. What it demonstrated over and over again (and what I have found a truth going through my own life), is that at the basis of every hard decision is a whole heap of values. And because I hold a set of values, and you hold a set of values, the real task is working through them, and doing that prioritisation that we just talked about here. That's the tough stuff, deciding, "ok, between us, what can we agree on, and get on and do something about, now." And good examples in this conference for me were things like the animal diseases. We have a relatively small window of time to deal with those animal diseases, in my view at least as a lay person. If we don't start doing something about them now and, in doing something about them, actually communicate that urgency to others who may influence the success or otherwise of the programs that you might have to introduce to manage those particular problems, we are not providing the best opportunity to achieve our goals.

One of the other things that I think is really important, is to understand that in any organisation there are a number of components. For me there's a learning component, and I'm talking about organisations in the very broadest sense of the word. So in terms of public land management, or in terms of managing the WHA (if you want to narrow it down a little bit) then there is the learning side, there is the planning side of it (and planning implies priority building), there's the implementation of those plans, and there's obviously the analysis of your success or otherwise. And importantly, there is the communication of what you're doing and why you are doing it. Most organisations typically do some of those things very well and other things not as well. But you can't do one without the others. And I suspect that one of the weaknesses with the group of people in this room (and I'd probably have to put myself and the WHA consultative committee in this same basket), is that we probably do quite a bit of learning — I think there's a good research base to a lot of what we do — we do a lot of planning, or at least we produce a lot of plans. I'm not sure sometimes, how good we are at prioritising the strategies in those plans. We often end up, like we tend to do here, with a long set of actions, but with not a lot of direction about what we ought to do first when we walk out of the room. And I think that's really important. I think that on the whole, we're very good at implementing. I've got lots of respect for our land managers, particularly for those people who are actually out at the coal face, implementing those plans. But what we don't do well in my view, and what we ought to be looking at, at some time in the future (which may mean getting more people from my walk of life, social science, management, in the room) is communication. The whole issue of 'how do we take others with us?' if we're ever going to achieve what we're talking about here, what we believe is important. Because as sure as hell, if you go out here and tell everybody that you're going to see the whole of the south-west, or the whole of the west, or the whole of the WHA, as an experimental area for fire management, you're going to get a range of responses and fairly quickly I imagine! And if you don't start thinking about how you're going to manage that communication issue, then you can sit in rooms like this for as long as you like and talk about it, but you're just not going to get anywhere.

Having said that, it's been a fantastic couple of afternoons for me, and I really commend the organisers of the conference, and the presenters of papers, all of which I found to be absolutely fascinating. I wish you well in the implementation of things that you have talked about today, encourage you to continue to run forums like this on a regular basis. Because it's only by the sharing of knowledge amongst others that I think we can go forward. And one of the exercises that I would have liked to see emerge from the workshop that I was in just a while ago (in fact it would apply to almost any of the past the two or three days), is to actually sit down with a big map up here, where we could put up the values we are concerned about and overlay them. And we'd see that, by the time we've finished, we'd have this mosaic that sits one on top of the other and we've got to just sit down and talk about how we're going to approach each of those little patches, if we're going to successfully managing them into the future. I hope that's been of use, I feel fairly humble, talking to a group of (on the whole) scientists and land managers, because although my knowledge is in management, it is certainly not in the scientific side. Although I have felt at home, because being a member of Tasmania's recently formed Threatened Native Orchid Task Force, and many orchids thrive after fire, I have felt comfortable being amongst a whole heap of pyromaniacs! Thankyou.

Post-workshop feedback from participants

Comments were received from participants following the workshop and have been summarised below by the editor. Participants sending in feedback included Tony Blanks, David Bowman, Sib Corbett, Michael Fletcher, Gintaras Kantvilas, Karen King, Michael Macphail, Jon Marsden-Smedley, Annie Phillips, Eddie Staier and Jennie Whinam. The source of each comment is provided as initials in brackets after each comment. A meeting of the workshop committee was convened on July 17 2007 to evaluate the workshop. The minutes of this meeting have been filed in the DPIPWE electronic records system and are freely available upon request.

Disappointments in Workshop

The workshop was not attended by any P&WS regional managers or senior managers from DPIPWE (JMS).

Not all talks were entirely pertinent to buttongrass moorlands (JMS).

Some researchers continue to present information that ignores the importance of fire in geo/biodiversity management and present only the potential negative effects of fire without acknowledging the importance of using prescribed management fires to prevent more negative impacts of wildfire (JMS).

Management priorities

It is imperative to control the spread of Chytridiomycosis in frogs to prevent local extinctions, action targets have been developed and will need compliance from land managers, tourists and operators etc. (AP)

There is a need for Tasmanian 'Ranger Guides' produced for each Bioregion outlining the Regional Ecosystems and their Conservation Values, which includes descriptions, conservation and management needs etc. This type of information needs to be made available through map info or a suitable Parks database delivery system (ES).

Opinions with respect to fire management

Comprehensive risk analysis/evaluation (including efficacy, impacts and cost/benefits) of various fire management options (ranging from do-nothing, to regular burning throughout region). Fires will occur (arson, lightning accidental escapes etc) and the impact of these wildfires under different prescribed fire management regimes need to be assessed to determine the ultimate cost/benefit of each approach. (JMS, DMJSB, JW)

P&WS need to "stop talking" and implement broad-scale burning regime the only obstacle to this is managerial, buttongrass moorland is logistically simple, and cheap to burn with a low risk of negative outcomes since it burns when nothing else can. It was clear from talks at the workshop that the biodiversity is relatively unresponsive to changing fire regimes. (JMS) If prescribed burning does not occur, then there will be more damaging wildfires (TB).

Researchers/specialists need to get together and agree on management objectives. The current system of individual comments which, which address a single-issue at a time and do not take the big-picture into account, obstructs fire management planning and operations. (TB)

"Before we embark on a quest to re-create some mythical, pre-European Arcadia in the south-west moorlands, let us remember that Aboriginal burning was a purely practical, expedient activity and did not manage for all biodiversity and other values. Research suggests that it had considerable impact on the landscape, such as removal of forest, fragmenting of sensitive conifer populations and ... other biodiversity losses. Let's have a sounder understanding of the vegetation and its components before we get out our matches and start playing God (or aboriginal)." (GK)

Fire management needs to take into account climate change, especially carbon storage and hydrology. (DMJSB)

Ecologically and economically sustainable fire management is a priority (DMJSB)

There was a general consensus that occasional prescribed burning is necessary in some areas for ecological habitat maintenance, e.g. orange-bellied parrot habitat. (JW)

Given that some prescribed burning will occur, then fire control and impact minimisation measures need to be developed and implemented. For example there is a need to identify fire management protocols that will protect assets such as organosols and *Sphagnum* peatlands from burning (JW).

Vegetation boundaries have shifted in prehistoric and historic times and there may not be any point managing fire to maintain stable vegetation boundaries (MM).

There wasn't general agreement for undertaking "fuel reduction burns" in wilderness areas. (JW)

It is important to keep wildfires/fires off steep slopes. (SC)

Research priorities

More inter-disciplinary scientific research is needed as well as collaboration between scientists and land management planners/ field staff. For example pre and post-burn studies, with scientists working with land management staff to achieve positive outcomes, and providing feed-back about the success or otherwise of each burn. (JW)

Investment in WHA and state-wide mapping is still required to meet management needs.

More consultation is required with stakeholders to ensure this meets their needs. There are problems with the existing mapping. (JMS)

Quantitative data is needed to prove the efficacy of broad-scale fuel reduction burning since there is a lack of substantive evidence that fuel reduction will provide protection to assets during extreme fire days. There are many examples where recently "fuel-reduced" moorlands have burnt again during wildfires, providing apparently little assistance in wildfire suppression. It is the extreme fire danger days which pose the most threat to biological assets, since these generally won't burn in lower fire danger situations. (JW)

More landscape-scale experimental trials are needed that quantify the effectiveness of fire management and environmental impacts. (JW)

Research into the impacts of fuel reduction burning has already shown that *Sphagnum* peats that appear fully saturated after 1 day of snow melt are still able to burn and be impacted by "cool prescribed burning". More research is needed to find better predictors of organosol flammability than the SDI. (JW, KK)

Research investigating the potential of plant phytolith to study the stability of vegetation through time has not yet been undertaken and may prove useful. (MF)

Further research on organosols and their inter-relationships with fire and carbon sequestration is required. (JMS, SC, MM)

It would be very valuable to continue to support specialists to undertake small-scale, local surveys and studies (e.g. of cryptic organisms). Small projects are relatively inexpensive and manageable, but they contribute to overall knowledge. (GK)

Revisit/re-evaluate the landscape ecology of SW Tasmania. (DMJSB, KK)

Changes to soils (peat) after wildfires and subsequent erosion. Such research could be undertaken at known wildfire edges such as King Range (1934 fires) western slopes of Ironbounds, Morain A/Scotts Peak (06/07 fire). (SC)

Research that would improve model accuracy and value for managers of 'FIRESCAPE Southwest Tasmania' (KK) includes:

- detailed data/ map layer of growth rates and succession times for each vegetation type showing local and regional variation in response to time since fire and factors such as propagule availability, climate, soils and geology;
- develop/modify FIRESCAPE so that it can investigate resilience of individual species to changes in fire regime;
- improve temporal and spatial estimates for soil dryness, fire ignition, fire propagation/spread and fire extinction thresholds for all vegetation types;
- improve estimates of spatial and temporal variation in weather parameters across the landscape;
- develop method to predict spatial and temporal variation in wind speed and direction for the landscape;
- investigate the implications of changing climate regimes on community dominant and species persistence in the landscape under different fire regimes.

Benefits of the workshop included:

The workshop:

- lifted the profile of buttongrass moorland and its values. (JMS)
- demonstrated that many people are willing to make serious changes to fire management practices in Tasmania (JMS)
- provided information that was not common knowledge such as the fact that *Phytophthora cinnamomi* has a greater impact on biodiversity of buttongrass moorlands than changing fire management regime and can result in local extinction of some plant species. (JMS)
- highlighted that *Chytrid* fungus is a real threat to biodiversity and could result in local extinction of some frog species if urgent action isn't taken to prevent it spreading. (AP)