TWWHA Bushfire Research Group
Lake Mackenzie
Alpine Fire Impacts Workshop

8 June 2016, University of Tasmania

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Cover photo: A section of Pine Bog, south of Lake Mackenzie, showing variable fire impacts on Pencil Pine and *Sphagnum.*

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Summary

On the 8th of June 2016, a workshop was held to discuss the impacts of the Mersey Forest Complex fires on the conservation values of the alpine area around Lake Mackenzie. The main goals of the workshop were to:

- Improve understanding of the impacts of the January 2016 fire on conservation values in the Lake Mackenzie area.
- Refine a system for defining sites with a very high or high priority for rehabilitation actions.
- Gather expert opinion on:
    - The likely trajectory of damaged areas.
    - The importance of intervening in the burnt landscape to achieve rehabilitation outcomes.
    - Rehabilitation techniques with the potential to improve outcomes in damaged areas.
    - Important monitoring targets and relevant monitoring approaches.
    - Important research questions for better understanding and managing fire impacts.
- Review the fire research needs and opportunities that feed into improved fire management.

The group discussion at the workshop agreed that important conservation values had been impacted by the fire. The most seriously impacted values included *Athrotaxis cupressoides* woodland, *Sphagnum* peatlands, and general soils. However, on a state wide scale, the impacts of the January 2016 bushfire was restricted to a small proportion of each of those conservation values. For this reason, there was support for the view that broad scale rehabilitation was not an appropriate response to this fire. However, it was felt that this fire presented a valuable opportunity to trial rehabilitation techniques appropriate for this environment, so that following the next alpine fire, land managers will be better prepared to respond.

Preventing further fire in this environment was seen as more important than rehabilitating damaged areas. The group recommended studies to better understand fire behaviour in the alpine environment and to identify parts of the landscape that may be most resilient in the face of climate change. This information is needed as an input for prioritising fire protection efforts.

The group raised a number of new research questions relevant to fire management in Tasmania.

Disclaimer

The views presented in this report may not reflect the opinion of all individuals attending the TWWHA Bushfire Research Group workshop, the University of Tasmania, the Department of Primary Industries, Parks, Water and Environment, the Tasmanian Government or the Australian Government.

1. Introduction

This report synthesises the discussions and conclusions from the Lake Mackenzie Fire Workshop held at the University of Tasmania on the 8th of June, 2016 (Appendix 1 – workshop agenda). The workshop was jointly run by the Natural Values Conservation Branch within the Department of Primary Industries, Parks, Water and Environment (DPIPWE), and the Centre for Environment at the University of Tasmania. The workshop was attended by a broad range of people with experience in fire management, fire ecology and research, or post fire rehabilitation (Appendix 2 – workshop attendees).

The main goals of the workshop were to:

- Improve understanding of the impacts of the January 2016 fire on conservation values in the Lake Mackenzie area.
- Refine a system for defining sites with a very high or high priority for rehabilitation actions.
- Gather expert opinion on:
    - The likely trajectory of damaged areas.
    - The importance on intervening in the burnt landscape to achieve rehabilitation outcomes.
    - Rehabilitation techniques with the potential to improve outcomes in damaged areas.
    - Important monitoring targets and relevant monitoring approaches.
    - Important research questions for better understanding and managing fire impacts.
- Review the fire research needs and opportunities that feed into improved fire management.

Structure of this report and how it relates to other reports

The structure of this report reflects the structure of the workshop. Material presented by DPIPWE staff to the workshop on the impacts of fire on particular values are summarised to provide context. The main points from the workshop discussion about the impacts, trajectory and possible management responses are summarised in a series of tables. The contents of these tables reflect views expressed during the workshop. They are not necessarily the views of the Natural Values Conservation Branch of DPIPWE, nor DPIPWE. The final session of the Lake Mackenzie Alpine Fire Workshop discussed research needed to improve fire management of natural values. This report used ideas generated in that session to update a previously published list of fire research needs (DPIPWE, 2015).

More detailed information on the fire impacts in the Lake Mackenzie area, and ongoing monitoring of post fire recovery, will be included in a report presently being drafted by the Natural Values Conservation Branch of DPIPWE.

At the invitation of the Tasmanian Fire Service (TFS), a Bushfire Rapid Risk Assessment Team (BRRATs) from Victoria prepared a report for the TFS documenting the scope of impacts on natural, cultural, social and economic values in the Lake Mackenzie region, and proposed post-fire responses. That report has not contributed to this report.

The State Premier allocated funds to investigate the implications of climate change for fire management in the TWWHA and more specifically to recommend fire management and suppression options with which to respond to the new risks. The interim report for that project (Press, 2016) was not available at the time of the Lake Mackenzie Alpine Fire Workshop group. It is probable the research projects recommended in the final report of that project will differ from recommendations posed in this report because the scope and objectives of the TWWHA bushfire and climate change research project report were different to the scope and objectives of the June 2016 bushfire workshop.

In March 2016 the Federal Government initiated a Senate inquiry into the response to, and lessons learnt from the bushfires in remote Tasmanian wilderness. Due to the July federal election, the inquiry had not reported at the time of the Lake Mackenzie Workshop. Because of differences in scope and objectives, the recommendations in this report may be different to those of the Senate inquiry when it is complete.

Location of fire impacts

The workshop was largely restricted to describing the impacts and potential responses to the Mersey Forest Complex fires on the highland woodlands, forests and treeless landscapes within the vicinity of Lake Mackenzie, Northern Tasmania. Several field sites are referred to in the text, particularly to locate photographs in the virtual tour. The locations of field sites are shown in Figure 1 together with the area of the Mersey Forest Complex fires and other 2016 summer wildfires.

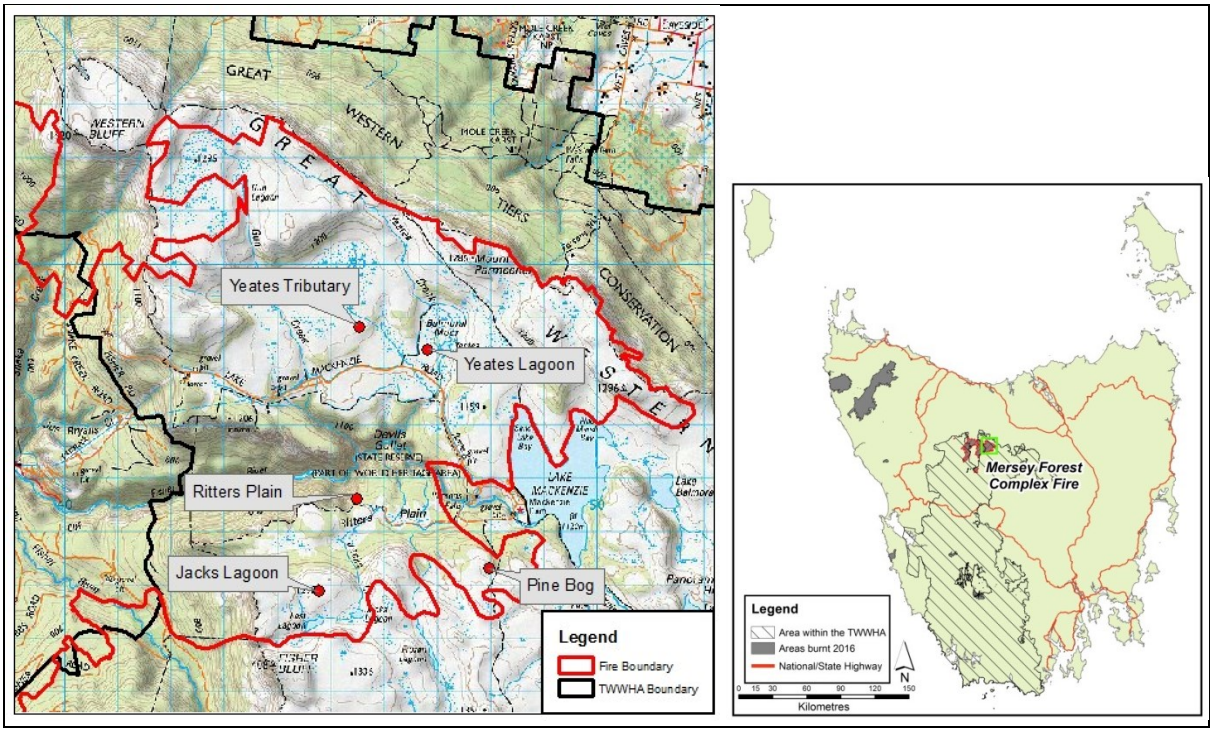

Figure 1. Left: Field sites referred to in the text (using The List 100,000 topographic base map, with a 1 km grid). Right: Distribution of the 2016 wildfires in Tasmania with green frame to indicate extent of field site map (left) within the area burnt by the Mersey Forest Complex fires.

2. Decision making tool for the identification of rehabilitation priorities

In the aftermath of the Mersey Forest Complex fires, there have been calls for rehabilitation of burnt areas, particularly in the alpine zone, to repair the damage to the conservation values of the Tasmanian Wilderness World Heritage Area. Rehabilitation can result in improved outcomes, but it is also time consuming, expensive, may be ineffective and may itself impact on other social and environmental values. Decision trees and other decision making tools are commonly used to assist identification of rehabilitation priorities, to help make decision making more targeted, transparent, and cost-effective. For example, a set of criteria were used to determine priority for restoration of mires following the 2003 fires in Victoria, New South Wales and the ACT (Good, 2009).

A first pass prioritising tool for rehabilitation works which incorporates input from the workshop is provided here (Table 1). It identifies criteria with which to qualitatively assess the highest priorities for post-fire response action. It is proposed for use first to assess the relative importance among different conservation values for rehabilitation actions, and secondly as a way of identifying which sites would be a priority for action for the rehabilitation of a particular value. Note that this matrix is not a quantitative tool that delivers a numerical value indicative of rehabilitation priority. Rather, it is intended to aid the clear identification of reasons for and against rehabilitation of a particular value or a particular site. These criteria were used during the workshop to make judgements on the relative priority of rehabilitation for different conservation values. The Natural Values Conservation Branch proposes to use this table to assess the priority for rehabilitation of fire damaged values and sites at Lake Mackenzie.

Table 1. Rehabilitation decision matrix tool.

This tool consists of a list of criteria to be assessed, and the qualitative characteristics used to judge the assignment of rehabilitation priority for each criteria. Colour coding is indicative of the importance of the criteria. Strong green/green indicates a very good/good reason to go ahead, strong red/red indicates a very good/good reason not to proceed.

Criteria		**Characteristics of Area, Value or Issue**		
		Very high priority	**High priority**	**Medium to low priority**
1	Potential for successful rehabilitation	Full recovery will be very slow, or is unlikely to occur without intervention, but there is very good potential for recovery that is much faster with intervention.	Significantly improved degree and/or rate of recovery with intervention.	Intervention won't significantly speed up or improve final recovery, because: • Initial damage was minor or natural recovery will occur before any further degradation occurs, or • There is no feasible rehabilitation option, or • Damage was severe and recovery will not occur even with intervention, or • Intervention likely to further damage remaining values, or • There is a well understood probability that the value will not be viable in the medium term (e.g. due to climate change)
2	Cost	Intervention will be very cost effective.	Intervention will be moderately cost effective.	Intervention not cost effective.
3	Importance level of value	International and nationally significant value.	State or regional important value.	Common and widespread.
4	Impact of the fire on conservation status	As a result of this disturbance, the security of the conservation value across the State is seriously reduced, because: • Remaining intact examples of the value are so rare or restricted in distribution that the class is highly vulnerable to significant further damage, or	Healthy examples of the value are significantly reduced in number or distribution within the region, but the value is still secure across the State.	The conservation value occurs with similar frequency to before the disturbance, or will naturally recover that frequency within 50 years.

Criteria		Characteristics of Area, Value or Issue		
		Very high priority	**High priority**	**Medium to low priority**
		• Value does not regenerate in present conditions, so all losses are permanent and cumulative.		
5	Fire initiated degradation processes	Ongoing degradation likely to cause significant and permanent change to the form or function of local ecosystem and landscape, impacting on a range of conservation values. May have off-site impacts.	Degradation will cause further losses of values in local area. Potential cumulative damage a major concern. Some potential for recovery in the long term.	Post-fire degradation processes either not present, or are naturally limited and will rapidly recover in a timeframe that makes cumulative damage unlikely.
6	Associated conservation values	Important values associated with damaged feature now dangerously vulnerable.	Important values are at some risk of damage.	Either no important values are associated with the damaged feature, or they are not threatened by the disturbance.
6	Rehabilitation research value	Experimental rehabilitation and monitoring will provide knowledge integral to improved management and rehabilitation decisions.	Monitoring and rehabilitation trials are likely to provide some useful input to future management.	Monitoring and rehabilitation trials are unlikely to change current management practices.
7	Social and political	Either: • Rehabilitation is required by management in response to intense political or public pressure, or • Examples of successful rehabilitation will generate support for ongoing TWWHA management.	Either • There is little or no political or public pressure to undertake rehabilitation. • The success or failure of rehabilitation will have no impact on future management decisions.	Either: • There is public or political pressure not to rehabilitate, or • Rehabilitation is likely to be unsuccessful, and will undermine efforts to do similar work after future disturbances.
8	Economic value	Damage to the feature will have a significant economic impact.	Damage to the feature will have a small economic impact.	Damage to the feature has no economic impact.

3. Fire impacts and response —discussion session

The main session of the workshop took participants on a 'virtual field trip' through the burnt area, concentrating on six major conservation values impacted by the fire (Table 2). In addition to the six main values, other values and threats arising from the fire were discussed last (Box 7, page 33). Each of the discussions aimed to answer seven general questions (Table 3). The main points that arose during the workshop discussions in answer to the seven questions for each conservation value are synthesised within boxes describing 'Fire impact and response' for each of the values (Table 2). Time was a major constraint on the workshop outcomes. The background presentations for each conservation value were allocated about 10 to 15 minutes, leaving only 5 minutes for small group discussion and 10 to 15 minutes for discussion among the full workshop of 40 people (Appendix 1 – workshop agenda and Appendix 2 - list of workshop attendees). Comments provided post-workshop have also been included.

Table 2. List of conservation values discussed in the workshop

Value	Box number	Page number
Peatland pool complexes	1	10
Pencil pine woodlands	2	14
Sphagnum peatlands	3	19
Soils	4	23
Cushion moorlands	5	27
Other forest and woodlands	6	30

Table 3. List of questions addressed in workshop discussion for each conservation value

Question	Row heading used in fire impact response boxes
How important is the value within the burnt area?	Conservation importance
How severely did the fire impact the value?	Fire impact
What is the post-fire trajectory for recovery likely to be?	Trajectory
What monitoring might be undertaken?	Monitoring
What are rehabilitation options or techniques might improve the rate of recovery?	Rehabilitation options
What is the priority for rehabilitation within the burnt area?	Rehabilitation priority
What are the priorities for future research?	Research needs

3.1. Peatland pool complexes

Background

Peatland pool complexes (in some cases also referred to as string bogs) occur on flat to gently sloping ground in association with a range of vegetation types. They occur both close to and far from drainage lines. There is a range of pool planform and vertical structure (Figure 2A). It is likely that the processes creating and maintaining the pools vary slightly depending on physical and floral context (Moore and Bellamy, 1974, Whinam and Kirkpatrick, 1994). However, the common pattern is that the walls enclosing the pools are formed from peat supporting live vegetation (Figure 2B). It is likely the pool walls are created in response to uneven growth rates in plants (Whinam and Kirkpatrick, 1994). Where plants grow most rapidly peat accumulates and water flow is blocked leading to enhanced growth conditions and peat accumulation on the wall and death of plants and cessation of peat accumulation in the flooded pool. However, periodically the pool walls are breached and the local hydrology is changed. Without the pool to maintain the soil moisture levels in the peat wall, it may dry out, oxidise and decompose, allowing a new pool wall to commence formation somewhere else.

Elsewhere in Tasmania peat pools have been reported to occur within *Empodisma-Astelia* tall alpine herbfield on Mt Wellington (Whinam and Kirkpatrick, 1994), and in cushion heathland at Newdegate Pass, Mt Field National Park (Gibson and Kirkpatrick, 1992; Kirkpatrick and Gibson, 1984). Within the Lake McKenzie area imagery and recent ground surveys suggest pool complexes are found in several TASVEG mapping units. They are most common in Eastern alpine sedgeland (Figure 2A), but also occur in *Sphagnum* peatland (Figure 2C) and Eastern buttongrass moorland. Cushion moorland is rarely associated with pools in this area.

Within the fire area, pool complexes form on flat to gently undulating valley floors. In broad valleys pools cover extensive areas, but they also occur in more confined settings. Though dominated by very low slopes, they have been observed on slopes up to 4°. In the burnt area the various areas of pool complexes vary in density, shape, orientation relative to slope, and whether pools are set into the broader plain or have walls raised above the plain (Figure 2). Although the peat pool complexes are likely to be of Holocene origin, they have not been dated and may be older.

The January fire burnt vegetation in these areas severely, removing much above ground biomass, exposing the fibric peat, and in places burning shallow scars into the peat. Resprouting of the vegetation has commenced but growth rates have been slow. The effects of browsing pressure and frost on resprouting plants and seedlings may reduce vegetative recovery leaving peats exposed to desiccation and mechanical erosion.

There is potential for erosion of fire damaged pool walls to lead to channel incision and gully erosion. Incision does occur in these environments in response to other disturbances such as vehicle tracks (Figure 2E). Once incision has created bare soil surfaces, frost heave promotes continuing erosion (Figure 2F). Post fire incision would drain directly affected pools, release sediment, and potentially impact the hydrology of the valley floor. Draining peat can lead to further peat loss through desiccation and oxidation. Changes to hydrology and sediment load could impact other pools in the surrounding area, and impact on water quality and quantity in receiving waterways.

Figure 2. A. Google earth imagery showing pool complexes (dark spots) near the western tributary of Yeates Creek north of the Lake Mackenzie road. B. A cross section through a raised wall of a pool wall in alpine sedgeland, Yeates Tributary. Note the fibrous nature of the peat. C. Pools in a mixture of sphagnum and sedgeland. D. The very thin walls separating pools at Yeates Tributary. E. Incised channel on an old vehicle track on Yeates Tributary. F. Pools near to the incised channel on Yeates Tributary. Note the retreat of the channel bank, probably driven by frost heave. Also, note that the pools within metres of the incised channel continue to hold water. However, rain shortly prior to the photograph means that the impact of incision on the hydrology of pools such as these is not clear

Whinam and Kirkpatrick (1994) suggested that fire had an impact on the *Empodisma-Astelia* pool complexes at Mt Wellington. They suggested that it was possible that fire damage in the bog may have initiated pool formation, but that high fire frequency was likely to cause erosion of walls and drain pools. Hope *et al*. (2005) observed erosion of peat dams in bog and fen communities of Kosciuszko and Namadgi National Parks following the 2003 fire. No detailed research work has been done on the floristics, hydrology, dynamics or fire impacts of the pool complexes in the Lake Mackenzie area.

Fire impacts and response in pool complexes – synthesis of workshop participant feedback

Box 1: Synthesis of workshop discussion for pool complexes

Question	Synthesis of workshop discussion and feed back
Conservation importance	• Pool complexes are likely to play an important hydrological role, holding water high in the catchment and releasing it slowly. • Pool complexes are likely to have geoconservation and fauna values (e.g. high invertebrate endemicity). However, these are un-documented in this area. • Different values may be associated with pools in different vegetation and geographic contexts.
Fire impact	• Significant combustion impacts on pools are minimal, with only minor charring of pool walls observed. • The probability of wall collapse and channel incision following fire will depend on factors including dominant vegetation, valley slope, contributing catchment, pool wall thickness and catchment size, and weather patterns until vegetation recovers. • Dam walls in sphagnum are likely to be fragile, while those in fibrous peat are more resilient. • Return period of fire may influence long term impact. • Pool complexes hold water higher in catchments. If the hydrology changes, it may impact both the hydrology of surrounding areas and the downstream catchment.
Trajectory	**Immediate post fire trajectory** • In sphagnum, pools are a late successional stage feature. They are very rare in disturbed areas (Ashton and Hargreaves, 1983). • In sedgeland, rapid vegetation recovery means pools are likely to be robust. • Risk of breach is related to local slope and catchment size as well as degree of fire damage. **Long term trajectory** • Drying trend increases vulnerability (20 years).

Question	Synthesis of workshop discussion and feed back
Monitoring	**Techniques** • Photo monitoring or physical measurement. • Remote sensing using drones, LiDAR and satellite imagery. **Focus** • Hydrology (water table height and run off, soil moisture). • Form (plan form and cross section). • Monitor pool walls for signs of failure which would trigger intervention to retain water. • Biodiversity. • Impact of future fires. **Challenge** • What is base line? Much of area is mapped as burnt in the 1960-61 fire.
Rehabilitation options	**Action** • Trial retaining water in an area, using active intervention early in fragile areas. **Focus** • Areas with best long term potential – consider future effects of climate change (fire frequency and hydrology). • Fragile areas (where pool walls are thin, slope is high and flow large).
Rehabilitation priority	• In general, rehabilitation on a broad scale is a low priority, and would only become higher if monitoring suggested widespread failure of walls. • Pool complexes in sphagnum may be higher priority.

Research needs	• What are the dynamics of pools in the alpine sedgelands?
	  ○ How old are they?
	  ○ How are they formed and maintained?
	  ○ Are they formed as a response to fire?
	  ○ Are they damaged by fire?
	• Thresholds of combustibility to better understand future threat.
	• Review of context – dangerous not to consider assumptions.
	• Where are water tables? Have canals and other hydro infrastructure affected hydrology and form already?
	• What conservation values are associated with the pools (flora, fauna, geomorphic)?

3.2. Pencil pine woodlands

Background

Pencil pine (*Athrotaxis cupressoides*) woodlands and forests are recognised as Threatened Native Vegetation Communities under the Nature Conservation Act – 2002. The genus *Athrotaxis* is known to be a palaeo-endemic clade of immense antiquity, dating back some 150 million years (Jordan *et al*., 2016). They are mentioned in the Statement of Outstanding Universal Values of the TWWHA (Department of Environment, undated). They are an iconic feature of the Tasmanian wilderness partly because they are very slow growing and very long lived. They are known to be extremely frost resistant, and it has been proven that regeneration is clonal in many areas, although to what extent new seedling establishment contributes to population turnover is not known. Under present conditions, successful establishment of new seedling/clonal shoots is rare. This is thought to be because of intense grazing pressure on young plants (Cullen and Kirkpatrick, 1988a), combined with the long period required to outgrow the browsing zone of Bennet's wallaby, although other factors are also likely to contribute to this.

The mapping of this vegetation type in TASVEG 3.0 (TVMMP, 2013) is indicative of the distribution, but over represents the total community extent. On the basis of the TASVEG 3.0 mapping less than 1% of Tasmania's pencil pine population was impacted by the 2016 fire. A project to remap this vegetation has commenced but it is unlikely to substantially change the estimate of the proportion of the community impacted by fire. Nevertheless, given the lack of regeneration it must be noted that all losses of pencil pine can be seen as permanent and cumulative. It is also worth noting that as the fire occurred on the northern boundary of the Central Plateau it has impacted on the very northern limit of the species range, with the reduction in population of pines in this area potentially contributing to a future reduction in range and corresponding potential loss of genetic diversity in the species (see Figure 3A). Many of the pine stands affected by this fire showed damage from at least one earlier event, with the 1960-61 fire known to have already killed a proportion of the pines in this area and injured others. The existing damage was demonstrated by the presence of many standing and fallen stags in and around stands and fire scars on many trees.

Pencil pines are mostly restricted to what had been thought of as fire refugia: sphagnum bogs, riparian zones and screes (Cullen and Kirkpatrick, 1988b; DPIPWE unpublished data). In the January fire, none of these environments were reliable refuges. Fire damage in pine stands ranges from unburnt, through scorched, to a full canopy burn. Fire carried well across sphagnum (Figure 3B), so that only individual trees in the wettest locations around pools survived relatively unscathed. Peat burning around roots is common (Figure 3C). In riparian zones, most pines are at least partly scorched, with some fully burnt (Figure 3D). Large screes formed the best refuges, with some large stands surviving the fire comparatively well (Figure 3E).

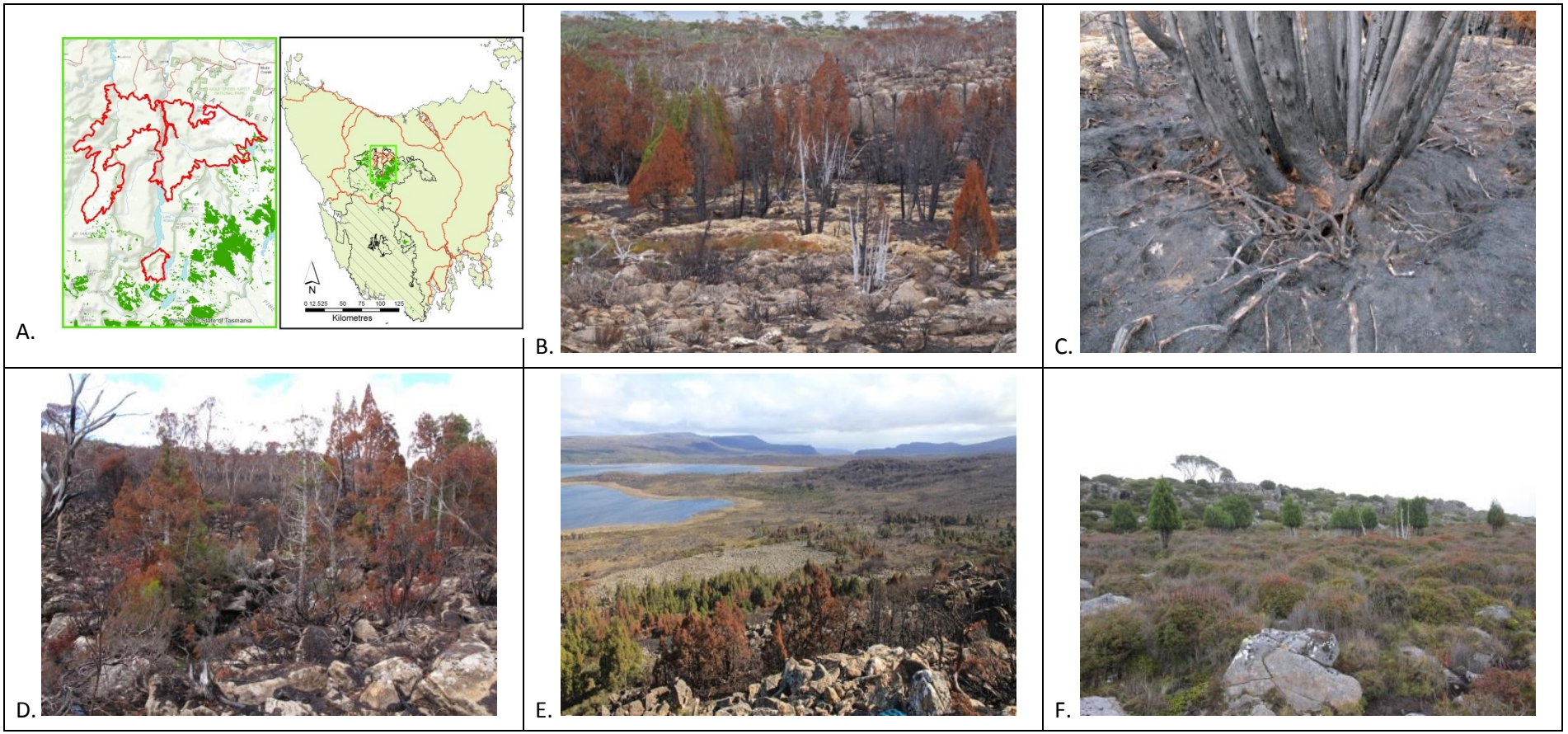

Figure 3. A. Mapped distribution of pencil pine forest and woodland (shown in green) in relation to the boundary of the Mersey Forest Complex fires (left) and the TWWHA boundary (right). B. Pine bog to the south of Lake Mackenzie. C. Localised loss of peat around a pine indicating extended smouldering. D. Pines in the riparian zone of Yeates Creek downstream of the Lake Mackenzie Road. E. Pines in scree to the north of Lake Mackenzie. F. Grazing pressure, upper Mickey's Creek.

Since the fire, there has been significant windthrow of pines. There was a propensity for trees which had existing fire scars (dead wood at the base) to catch and smoulder internally with many then falling during or in the months post fire. Windthrow was not observed in any trees which did not have existing scars. A majority of windthrown stems still carried green leaves, suggesting that smouldering in the trunk usually doesn't occur where fire behaviour leads to leaf scorch or a canopy fire. It appears that pines in these relatively protected locations survived one fire (probably 1960/61), but the cumulative impact of successive fires has proved fatal.

Grazing is an issue for pine regeneration as demonstrated by trees which have had their lower branches severely pruned (Figure 3F). Of the stands of pine observed within the fire area, only one near Jacks Lagoon lacks evidence of grazing and included small plants. It is not clear whether this variability in grazing pressure is due to a local variation in the grazer population, or a difference in the palatability of this particular stand of pines. It is also not clear if there will be any impact of greater grazing intensity on surviving stands following the fire.

Fire impacts and response in pencil pine woodlands – synthesis of workshop participant feedback

Box 2. Fire impacts and response in pencil pine woodlands – synthesis of workshop participant feedback

Question	Synthesis of workshop discussion and feed back
Conservation importance	• Big patches of old pine were a significant value. • Although only a small proportion of the state's pine population is likely to have been killed in this fire, losses are significant because they are likely to be permanent. • Losses have a high social value as these pines are very accessible and are an iconic TWWHA value. • The area impacted by this fire is not true wilderness, as it has been impacted by the 1960-61 fire, hydro developments and by visitor affects. Although this means the area has less value as a wilderness, it does make the area an appropriate place to run rehabilitation trials. • The fauna of pine stands may be a value, but is not well understood.
Fire impact	• High impact within burnt area. • Pines in sphagnum most affected.

Question	Synthesis of workshop discussion and feed back
Trajectory	**Immediate post fire trajectory** • Unlikely recovery if scorched. • Regeneration is mostly through clonal sprouts. • Regeneration (clonal or seedling) unlikely to succeed because of grazing pressure and competition from grasses in grassy areas. **Long term trajectory** • Internal areas of some patches not burnt – they are likely to survive this fire. • Pines are obviously vulnerable to loss through fire, and also to other climate change impacts (DPIPWE, 2010). Across whole population of pines there is likely to be variability in the vulnerability to loss from fire or other climate change impacts. The Lake Mackenzie area appears vulnerable to fire (evidence is that it burnt in 1960-61 and this fire). If we can understand that vulnerability, we could use that knowledge to classify this and other areas of pine as more or less vulnerable, and so identify areas most likely to survive in long term.
Monitoring	• To understand how rates of recovery are related to intensity of impact and environmental factors. • Is grazing an issue in all stands (burnt and unburnt), Jacks Lagoon and other areas? • Recovery of patches with unburnt centers. • Recovery of partially scorched trees.
Rehabilitation options	**Action** • Keep sphagnum wet in high priority areas (irrigation?). • Plant on screes (site fire protection). • Plant unpalatable genotypes. • Use grazing enclosures with care as there is experience of them not working in dense grassland enclosures in Walls of Jerusalem (Cullen, 1987). **Focus** • Map burnt and unburnt patches of pine within fire boundary and beyond. • Protect unburnt patches. • Priority areas for management should be identified with care, and may not be within the fire boundary. The fact that this area burnt in the 1960/61 fire and this one suggests that it is vulnerable to fire. Priority should be given to areas with best long term chance of viability in the face of future fire and climate change.
Rehabilitation priority	• Broad scale rehabilitation is a low priority. • Trials are a higher priority, to improve management response to future fires.

Question	Synthesis of workshop discussion and feed back
Research needs	**Understanding fire behavior in pines** • Are trees older on screes? That is, have screes always been a more reliable fire refuge than sphagnum? • Assess how fire moves onto and around dense stands of pine to better predict future impacts. • Did the 1960-61 fire have a different impact to the 2016 fire, and what does that tell us? • Examine role of shrub presence (*Richea scoparia*) in promoting fire. • Research thresholds of combustibility. **Understanding values of pines** • What are fauna values and are their taxa dependent solely on pines? **Managing pines into the future** • Experiment with regeneration techniques – use opportunity to assess rehabilitation options for future fires. • Can the fire hazard around pencil pines be reduced to significantly improve survivability without significant adverse impacts? • Drought tolerance (they do get drought stressed)? • Identify areas most protected from climate change and future fire. Where are the most secure refugia (geographic region and habitat)? • Identify low palatability genotypes (e.g. the stand near Jacks Lagoon) and trial seedings of this genotype. • Pine scree slopes vs sphagnum – what does this tell us about landscape soil moisture and ground water? • How best to manage unburnt areas? • Note that several pine monitoring projects are already underway. • Prioritize revision mapping of pine communities. **Community values** • This is part of the TWWHA, where wilderness is highly valued. What interventions would the community view as tolerable? What is the threshold between Wilderness and Garden?

3.3. Sphagnum peatlands

Background

Sphagnum peatlands are recognised in Tasmania and nationally as a Threatened Native Vegetation Community. The community also supports other significant flora and fauna, such as pencil pine (Figure 4B). As well as the biological values, sphagnum peatlands form a distinctive type of landform which has geoconservation value. Striped mires described by Morgan *et al*. (2010) are considered to have Outstanding Universal Significance within the TWWHA (Department of the Environment, undated). Sphagnum is associated with some depth of peat deposits (e.g. Figure 4C) (Whinam *et a*l., 2001), which are an important carbon store and also hold a paleo-environmental record. Sphagnum peatlands also influence quality and quantity of water flowing out of a catchment (Worboys *et al*., 2011).

A National Recovery Plan (Department of the Environment, 2015) specifies efforts that should be made to ensure recovery of sphagnum after disturbance, but lacks Tasmanian specific detail on the thresholds for action and what action should be taken. It mentions as high or highest priority: 'Develop an ecological procedure for assessing fire impacts and required responses'; 'Develop and implement targeted management responses for fire affected areas', and 'Undertake restorative trials and revegetation works to assist bog recovery after stochastic events'.

Recent revision mapping available in TASVEG LIVE (TVMMP, 2016) indicates that the 68 ha of sphagnum peatland burnt was probably only 1.5% of the total statewide extent (Figure 4A). All sphagnum peatlands observed within the fire boundary have suffered significant damage. Overall, sphagnum peatlands typically show a complex mosaic of fire damage ranging from minor to significant (Figure 4D). Extensive areas are very badly burnt, with the *Sphagnum* moss killed and a significant depth of peat lost (Figure 4E). This level of damage frequently occurred where a shrubby overstorey existed prior to the fire. In the wettest areas, particularly surrounding pools, *Sphagnum* moss has survived intact (Figure 4F.).

Since the fire, some resprouting of scorched moss has been observed. However, based on the mainland experience, post fire degradation of sphagnum is likely, caused by the increased exposure of live moss to wind and UV light, and through stream erosion (Good *et al*., 2010; Whinam *et al*., 2010).

Extensive post fire rehabilitation of sphagnum has taken place in Victoria, New South Wales and the ACT following fires since 2003 (e.g. Good et al., 2010; Whinam *et al*., 2010). A variety of techniques have been used successfully and could be trialled here.

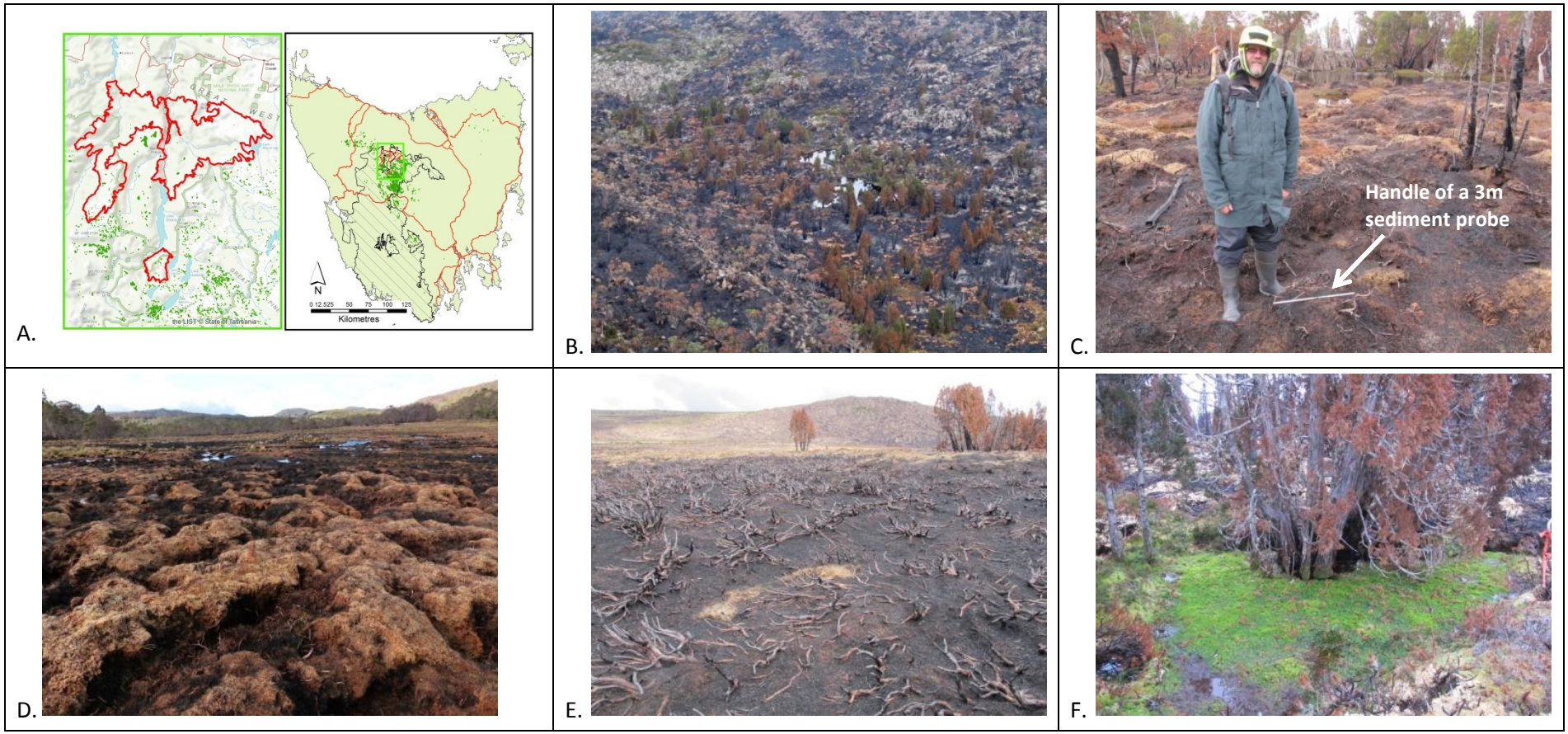

Figure 4. A. Sphagnum peatlands distribution within the area of the Mersey Forest Complex fires (left) and the statewide distribution (right). B. Burnt areas of Pencil pine woodland within a Sphagnum peatland valley. C. Peat depth in Pine Bog exceeds 3m at deepest point. D. Variable impact of fire on sphagnum at Ritters Plain. E. Intensely burnt sphagnum peatland at Jacks Lagoon. F. Surviving remnant of Sphagnum at edge of pool, Pine Bog, south of Lake Mackenzie.

Fire impacts and response in Sphagnum peatlands – synthesis of workshop participant feedback

Box 3: Synthesis of workshop discussion for Sphagnum peatlands

Question	Synthesis of workshop discussion and feed back
Conservation importance	• Sphagnum plays an important role in hydrology, retains water in catchment and reduces flash flood events, keeps soil moist and comparatively safer from deep burning fires. • Sphagnum is an ecosystem engineer that creates a distinct environment (hydrology, pH) which is a habitat for other flora values (e.g. pines) and fauna, particularly frogs and invertebrates. • Influences water quality (lower pH, nutrients e.g. (Silvester, 2009)). • Water has an economic as well as environmental value.
Fire impact	• Badly burnt areas are not recoverable, even with intervention.

Trajectory	**Immediate post fire trajectory**
	• Work on the mainland (e.g. Good *et al*., 2010; Whinam *et al*., 2010) suggests that post fire trajectory depends on:
	  ○ degree of damage to sphagnum and to overstorey plants,
	  ○ type of peat remaining,
	  ○ ground and surface water flows,
	  ○ presence of healthy sphagnum nuclei from which to colonise degraded areas.
	• Loss of shade, increased wind and UV exposure and moisture loss will lead to further degradation.
	• Sphagnum pools are important for recovery, but are likely to be fragile and may collapse.
	• Natural recovery unlikely to occur in badly burnt areas – no regeneration in Vic and NSW after 13 years.
	Long term trajectory
	• Repeated fire would be likely to eliminate Sphagnum peatland communities.
	• This community is likely to suffer accelerated decline with climate change.

Monitoring	• Compare hydrology of burnt catchment vs unburnt – not yet done in Tasmania. • Understand how rates of recovery are related to intensity of fire impact and environmental factors. • Vegetation recovery monitoring. • Peat depth and characteristics. • Fate of landform and function (hydrology, peat maintenance and continued deposition) where sphagnum has been killed and is replaced by another community.
Rehabilitation options	**Action** • Review techniques used in successful rehabilitation on the mainland to identify methods to trial here. • Use shade cloth to imitate natural shading. It reduces evapotranspiration, and increases precipitation through fog interception. • Manipulate ground and surface water flows to maintain wetness and prevent stream incision.

Question	Synthesis of workshop discussion and feed back
	• Where biosecurity considerations allow, use relatively soft barriers (e.g. straw bales, coir logs) to maintain pools. • Transplant sphagnum nuclei into broad degraded patches. **Focus** • Identify naturally resilient areas, and areas minimally damaged.
Rehabilitation priority	• Rehabilitation on a broad scale is a low priority. • Triage severity of burn areas and which areas are more likely to recover (learn from NSW/Vic experience). • Identify naturally resilient areas. • Areas with live nuclei of sphagnum.
Research needs	• Holds nutrients – can this buffer against loss? Data from NSW/Vic. • Research thresholds of combustibility. • Examine role of shrub invasion (*Richea* species) in promoting fire. • What level of damage will sphagnum recover from, and how does this relate to the local environment? • What can be learnt from the 1960's fire? Which areas are susceptible to damage, which are resilient, where has recovery occurred?

3.4. Soil

Background

Soils are the interface between the bedrock environment and the ecosystem. They support flora and fauna values, and are a basic control on nutrient cycling and water movement through the landscape. They are vulnerable to direct fire damage through combustion of organic horizons and through changes in characteristics such as hydrophobicity (Doerr and Shakesby, 2013). They are also vulnerable to ongoing erosion post fire as a result of changes to hydrology and soil surface protection caused by the loss of vegetation (e.g. Storey and Comfort, 2007).

Soils within the fire area are very variable. They include very rocky mineral soils on the slopes and gentle rises, alpine humus soils of grassy sedgelands (e.g. Figure 5A), and organic soils and peats associated with sphagnum bogs and alpine sedgelands. In the wet and cool environment of this area of the TWWHA, organic decomposition rates are slow, so that the mineral soils typically have a surface and litter horizon that is sufficiently organic to burn. Combustion of the soil surface has been observed in all environments. At this stage, there is no data on the proportion of different environments directly impacted by fire.

Soil loss falls into shallow or deep combustion patterns. Observations suggest that shallow loss of the most fibrous surface layer of the organic horizon is widespread. This loss is usually restricted to the top few centimetres of soil, sometimes approaching ten centimetres deep. Across this burnt area, the fire was sometimes but not always sufficient to kill the deeper roots and rhizomes, or to destroy the entire seed store. Burnt patches vary in size, but are typically restricted to areas of a few square metres in a complex mosaic of burnt and unburnt soil. Some organic horizon usually remains present, except on the shallow mineral soils of the bedrock rises associated with alpine shrublands and *Eucalyptus coccifera* woodlands.

Deep soil combustion is usually restricted to the better drained areas such as areas disturbed by road or canal construction (Figure 5D), some stream banks (Figure 5E), some cushion moorland, or highly organic soils where shrubs or trees acted as wicks to carry the fire deeper into the profile. In these areas, fire has extended over 10 centimetres, often leaving a distinct red or orange ash layer. No resprouting or regeneration was observed in these deep burnt areas, implying the death of roots and seedbank.

Burnt soils of all types are likely to suffer ongoing mechanical erosion driven by frost heave (Figure 5F). Frost heave detaches crumbs of soil from the surface where they can then easily be removed by wind or water. These processes continue to cause active soil erosion on the Eastern Central Plateau 50 years after the 1960/61 fire (Cullen, 1995; Storey and Comfort, 2007). It is too early to tell how the post fire erosion will progress in the Lake Mackenzie area.

Nutrient movement and losses will occur as a result of the fire. Some nutrients will have increased availability in ash following fire, while others are volatilized and are lost from the system (DeBano, 1990). Nutrients in ash and detached soil particles can be transported, potentially increasing nutrient availability in depositional areas while reducing it in source areas.

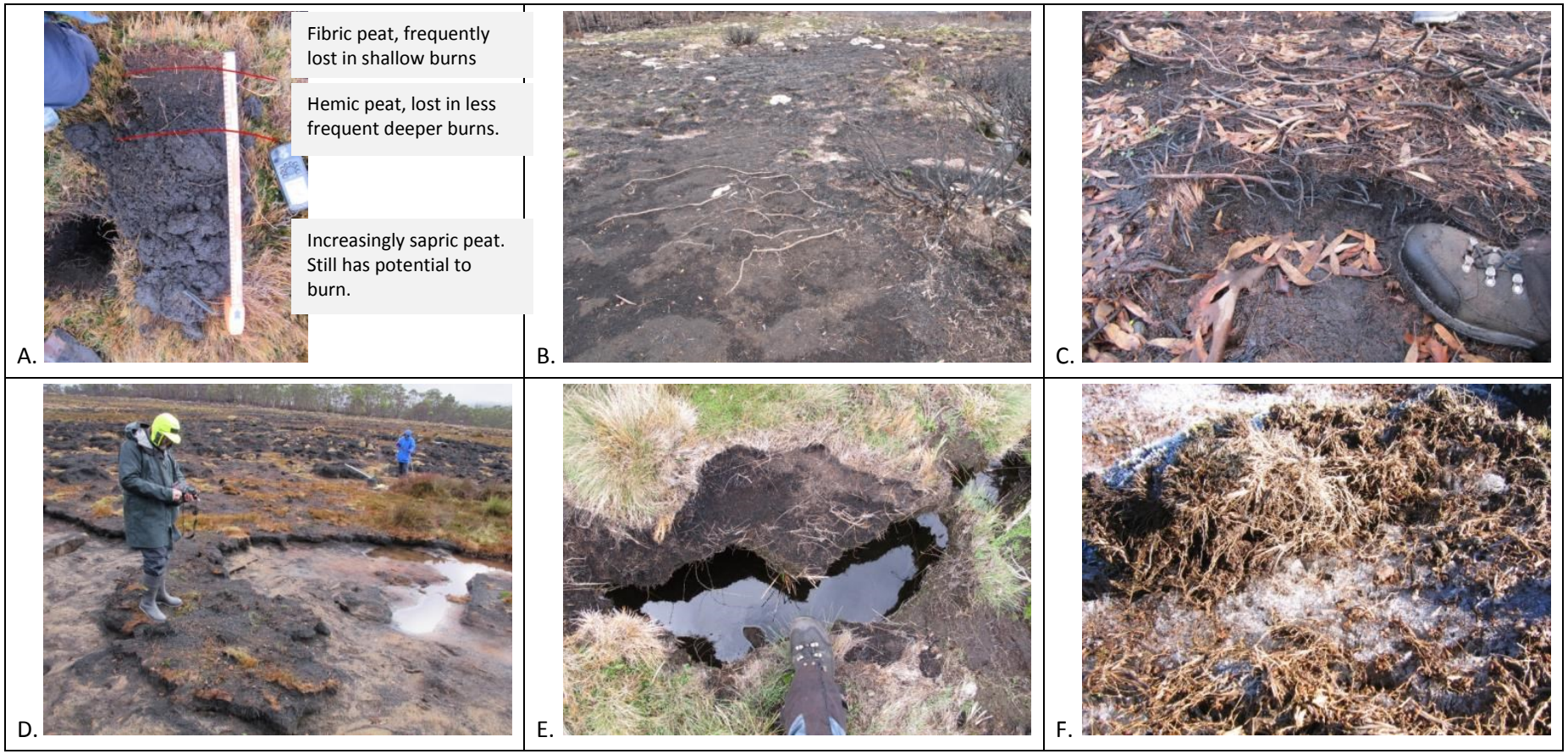

Figure 5. A. Alpine humus soil at Ritters Plain. B. Shallow burn alpine humus soil, Ritters Plain. C. Burnt organic horizon, *E. coccifera* woodland, Yeates Lagoon. D. Deeply burnt (>15 cm) alpine humus soil, Ritters Plain. E. Burnt riparian soil, Yeates Creek. F. *Poa* uprooted by frost heave, near Bernacchi on the eastern Central Plateau.

Fire impacts and response in soils – synthesis of workshop participant feedback

Box 4: Synthesis of workshop discussion for soils

Question	Synthesis of workshop discussion and feed back
Conservation importance	• Soil has geoconservation value in its own right. • Also supports flora and fauna conservation values. • Carbon store. • Ecosystem services - cycles nutrients, filters water, influences hydrology. • Economic value in water yield and water quality.
Fire impact	• Macro level – sediment movement downstream. • Soil buffers of water, carbon and nutrients will be impacted.
Trajectory	**Immediate post fire trajectory** • Lose matrix and buffer for vegetation. • Frost heave gets into bare ground and drives erosion. • Weeds and deer may respond to soil and vegetation disturbances. **Long term trajectory** • Repeated fires likely to dramatically increase area and depth of burnt soil. • Frost heave may continue to cause erosion in the long term even without other disturbances.

Monitoring	• Better mapping of soil properties in strategic areas.
	• Soil temperature and moisture content, desiccation cracking.
	• Monitor water tables in deep peat.
	• Thresholds of soil damage leading to ongoing erosion problems.
	• Ongoing erosion problem:
	  ○ Establish the size of the problem.
	  ○ Trial control measures.
	  ○ Use a range of techniques, from remote sensing to citizen science.

Rehabilitation options	**Action** • Review and trial techniques that have been successful in mainland alpine areas (e.g. hydro mulch). • Experiment with techniques for slowing water down, and redirecting flow. • Weed control, deer control. **Focus** • Look after intact areas with high recovery potential. • Use modelling to predict the risk and consequence of frost heave using vegetation, soil hydrology, topography and soil characteristics. E.g. frost heave is worst where there is groundwater emergence and soil has a high clay content.
Rehabilitation priority	• Broad scale rehabilitation is a low priority. • Protect areas that are unburnt. • Resilient areas as identified by a landscape scale soil risk assessment.
Research needs	**Soil and sediment processes** • Where does eroded material end up? • Carbon budget – fluxes, sequestration. Does fire speed up emissions? • Can frost heave intensity be predicted by soil hydrology, vegetation, topography and soil characteristics? • Sampling and mapping of soil properties using a combination of field work and

Question	Synthesis of workshop discussion and feed back
	modeling. • Monitor water table, soil temperature, moisture content. • Hydrological experiments – water holding modifications. • Research stratigraphy to better understand soil development. • Impacts of existing Hydro infrastructure (dams, drains and canals). **Soil values** • Soil invertebrates and their resilience to fire are not well studied. • How much is the soil landscape worth in broader sense (carbon store, ecosystem services)? **Fire management** • Thresholds of combustibility – when does a peat become a fuel and how does that influence fire behaviour. • Are there tipping points for soils that have a significant impact on fire behaviour (temperature, cracking, soil moisture)? **Community values** • The social science of natural processes vs intervention – how much intervention can we do in the TWWHA without impacting on wilderness values? • Cost of not acting – economic cost of ecosystem services (broader impacts). • Can citizen science be used to monitor ongoing soil erosion?

3.5. Cushion moorland

Background

Cushion moorland is recognised as a Threatened Native Vegetation Community under the Nature Conservation Act – 2002, and as an Outstanding Universal Value of the TWWHA. Cushion moorland is also an iconic feature of the TWWHA. Within the fire area, cushion moorland is formed of stands of *Abrotanella forsteroides*. *Pterygopappus lawrencei* is present occasionally on some of the cushions, but more typically there are herbs and shrubs growing from their surface. The individual cushions are surrounded by restionaceous sedgeland plants. Cushion plants in this area occur in wet areas on gentle slopes. Although cushion plants sometimes contribute to the development of dam walls in pool complexes in other regions of Tasmania, this does not appear to be the case here.

The TASVEG mapped extent of cushion moorlands is currently a very poor indicator of its distribution or extent of this rare vegetation type. Despite this it is likely that the area of this community which was burnt by the Mersey Forest Complex fires was only a small proportion of the total extent.

Cushion moorlands occur in saturated habitats. This along with the smooth surface of the bolster would usually make them resistant to catching alight and burning. These features do not appear to have protected the plants during this fire. Given the conditions at the time of the fire the combustibility of the cushions appears to have been high, once ignited the propensity for the cushions to smoulder appears to have meant the fires residence time was far greater in the cushions than the surrounding sedgelands. The post-fire remains of the cushion moorlands in the Lake McKenzie area demonstrate that emergent shrubs and sedges had often allowed an entry point for the fire into the cushion surface and around its lower edge. Fire impacts ranged from complete combustion (Figure 6A and B), in some cases to below the original soil surface, to superficial scorching (Figure 6C). In many cases a large proportion of the cushion circumference was burnt away at the base of the cushion (Figure 6D). In the worst affected areas, shortly after the fire, the previous existence of cushions was only evidenced by a bed of fine ash. Typically, larger stands of cushion plants show a range of fire damage (Figure 6E).

Abrotanella forsteroides is a member of the daisy family, Asteraceae. It is unclear what levels of fire damage the cushions can survive. Resprouting has been observed in scorched zones of bolsters. However, damage to the structural form may result in less protection against frost, ice bearing winds, and exposure to desiccation, even where a portion of the bolster remain alive. This may cause collapse of the cushion structure and ultimately a delayed death. The seeds of *Abrotanella* have no pappus or other noticeable traits for dispersal, which suggests a highly limited dispersal range. Seed may have survived in the soil or in unburnt layers of vegetation and litter, and so allow cushion moorland to re-establish in areas where most plants have been killed. However, there is some evidence to suggest that cushions damaged in earlier fires have been colonised by restionaceous sedgeland, rather than returning to cushion moorland (Figure 6F). Existing studies of cushion moorland dynamics that may be useful in understanding behaviour here include (Gibson, 1989; Gibson, 1990; Gibson and Kirkpatrick, 1992; Kirkpatrick and Gibson, 1984).

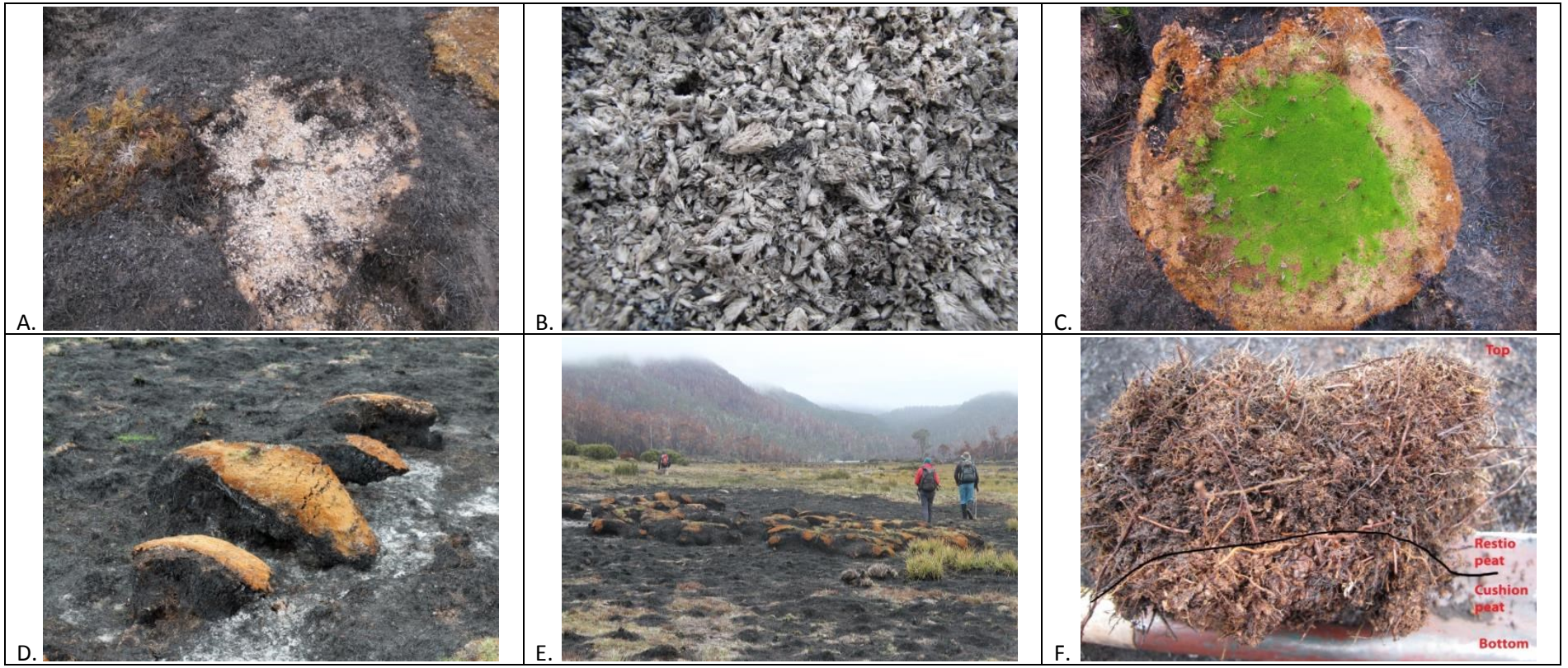

Figure 6. A. Completely burnt cushion plant several days after fire, near Sandy Lake Bay. B. Ash created by slow smouldering of a cushion plant. C. Zones of fire impact. From the outside of the bolster to the centre, a completely burnt area at the top left, a ring of fire killed plant, a ring of scorched and resprouting plant, and a central zone of intact plant. It is not clear which if any parts of this bolster will survive in the long term. D. Remains of cushion plants where fire has undercut the bolster around the circumference at Lake Bill. E. Variably impacted area of cushion moor. F. Cross section from a restio tussock showing that it is formed on cushion peat. This suggests that this particular tussock has changed from cushion moor to alpine sedgeland following some past disturbance.

Fire impacts and response in cushion moorland – synthesis of workshop participant feedback

Box 5: Synthesis of workshop discussion for cushion moorland

Question	Synthesis of workshop discussion and feed back
Conservation importance	• Social value of iconic TWWHA value in an easily accessible place.
Fire impact	• High impact within burnt area.
Trajectory	**Immediate post fire trajectory** • Partially damaged cushions may take a long time to die in response to lost thermal buffering. • Cushion on slopes now subject to erosion forces. **Long term trajectory** • Cushion moorland has the potential to regenerate relatively quickly through seed. • There is potential for community change to sedgeland where soil seed sources have been killed. • Climate change impacts on hydrology and temperature may threaten unburnt areas.
Monitoring	• Will the vegetation type regenerate where many individuals have been killed? • Investigate how rates of recovery are related to intensity of impact and environmental factors. Photo monitoring will be appropriate.
Rehabilitation options	**Action** • Retain water to protect intact cushions. • Preventing soil erosion is likely to assist cushion recovery. • On slopes manage overland flow erosion threats. • Attempt very small scale trial, monitoring ~20 control and treatment pairs, in which surviving parts of treatment cushions are extracted and replanted at a depth which ensures the plant is protected from wind, frost and drying out, and survival rates compared between treated and untreated paired cushion.
Rehabilitation priority	• Broad scale rehabilitation is a low priority. • Cushions are a lower priority than sphagnum or pines, but will benefit from actions to protect other values (e.g. soils etc.). • Important to use this opportunity to learn about impacts and mitigation options to improve response to future events.

Research needs	• Use this fire for natural experiment to understand future impacts.
	• Degree and type of damage that cushions can recover from.
	  ○ What degree and type of damage that cushions can recover from?
	  ○ Will the vegetation type regenerate where many individuals have been killed?
	• Should cushion plants be a priority for fire suppression actions in future fires?
	• Does the distribution of cushion plants post 1960's fire tell anything about resilience and recovery?
	• Improve mapping of the community.

3.6. Forests and woodlands

Background

The Mersey complex fire burnt substantial areas of a range of forest types, including dry eucalypt forest, wet eucalypt forest, rainforest and non-eucalypt forest. The response to the fire varied with vegetation type, fire intensity and elevation. Across all forest types, repeated fire in the short term (< 50 years) would lead to a greater impact than a single fire. This interval is determined by the time needed for plants to reach a size sufficient to survive fire and for seed banks to be replenished.

Fire impacts in eucalypt forest are less severe than other vegetation types. Episodic fire is a natural and important element for the maintenance of this ecosystem and recovery will occur naturally in most places. Species are adapted to survive or recover from fire by resprouting. Seed germination is often triggered by fire either through the release of aerially stored seed or germination of soil seed bank. Note the seed store will be depleted for many years, leaving vegetation vulnerable to a second fire.

Fire intensity varied widely in the eucalypt forests. In most situations the canopy trees have survived and will resprout from epicormic buds in the trunk (Figure 7A and B), or in the case of highland *Eucalyptus coccifera* woodlands from lignotubers (Figure 7C). Many of the understorey species are also recovering by resprouting. In addition the fire has triggered germination of soil stored seed and seedlings were observed in the May 2016 ground surveys, although at relatively low densities. In the most severely burnt areas intense crown fires and ground fires are likely to have led to a higher mortality of trees. This fire intensity mostly occurred in very steep and difficult to access locations, and has not been assessed on the ground. It is not known what proportion of eucalypts survived in these areas, or what impact the crown fire has had on canopy stored seed or the soil seed store. Where canopy held seed has been killed, there will not be a return to eucalypt forest in the immediate future.

The rainforests are less well adapted to fire: they comprise species which are usually killed by severe fire, although they do resprout after less severe fire. The dominant; *Nothofagus cunninghamii* has very limited seed dispersal capacity and few rainforest species have a soil stored seed. Stands where all trees are killed may revert to *Acacia* or Myrtaceae dominated scrub.

Rainforest forms a relatively small proportion of the burnt areas. Rainforests occur in relatively fire protected habitats, but despite this, the January 2016 fires did burn through many stands. Although fire intensity was variable and mostly fairly low (e.g. Figure 7D) there were small patches of more intense damage (e.g. Figure 7E). Nevertheless limited observational evidence suggests that many of the rainforest patches were not completely burnt, and that some burnt trees are re-sprouting (Figure 7F). Surviving plants will serve as a seed supply for the regeneration of rainforest species within the burnt patches, ensuring that in the long term most patches will return to rainforest. In the short term, pioneer species such as *Acacia,* if they are present in the

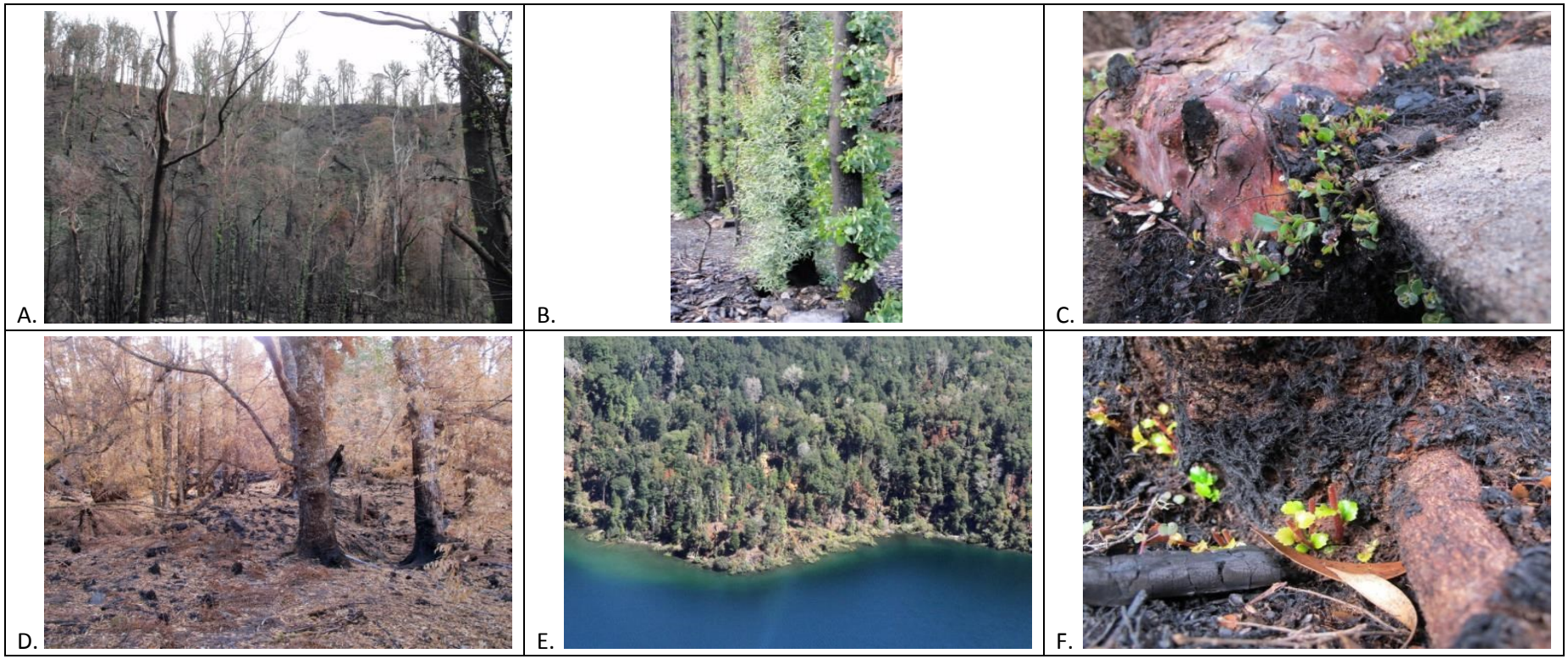

Figure 7. A. and B. *Eucalyptus amygdalina* trees on the slopes above the Fisher River Power Station where canopy fire, resulted in loss of crown foliage but trees are now resprouing from epicormic buds up the trunk. C. The upper limbs of *Eucalyptus coccifera* woodland trees have been killed at Yeates Creek but they are resprouting from basal lignotubers. D. Patch of burnt rainforest at Maggs Mountain, demonstrates fire scorched but did not burn the canopy here, scorched leaves litter the ground. E. Fire has trickled around the understrey of a highland rainforest patch at Lake Louisa, scorching the canopy of some trees and burning peat; trees at the edge of the lake have collapsed. F. Some resprouting at the base of *Nothofagus cunninghammii*. Resprouting trees will reach maturity more quickly than seedlings.

soil seed bank (Hill and Read, 1984), are likely to dominate the burnt rainforest patches, providing a nursery crop which will protect the rainforest seedlings from excessive exposure. The opening of the canopy is likely to increase wind-throw events (Neyland and Brown, 1994), a pattern already evident in the pencil pine forests and woodlands.

At all elevations, grazing pressure on resprouting plants and seedlings is likely to be intense (Hill and Read, 1984).

Fire impacts and response in forests and woodlands – synthesis of workshop participant feedback

Box 6: Synthesis of workshop discussion for forests and woodlands

Question	Synthesis of workshop discussion and feed back
Conservation importance	• Tall forests are visually very obvious to the community, however media attention during the fire event was focused on pines. • Rainforest is an iconic value.
Fire impact	• Fire impacts in eucalypt forest are less severe than other vegetation types. • The rainforests are less well adapted to fire. Stands where all trees are killed may revert to *Acacia* or Myrtaceae dominated scrub. • Repeated fire in the short term (< 50 years) would lead to a greater impact.
Trajectory	**Immediate post fire trajectory** • Stands of fire adapted stands will regenerate through resprouting and seed release and germination. • Areas where canopy held seed has been killed will not return to eucalypt forest in the immediate future without active intervention (reseeding). • Could be a reduced abundance of rainforest species or even a switch from rainforest to scrub where rainforest patches have been intensely and completely burnt. • Empirical research and predictive modelling suggest treeless plant communities at high elevation are at increasing risk from invasion from naturalized exotics, sleepers (McDougall *et al*., 2005, Duursma *et al*., 2013) and it is likely this risk will be even greater in the post-fire environment. **Long term trajectory** • Could be ecosystem changes in some forest areas depending on fire severity, range of possibilities. • Depleted seed stores in canopy and soil mean that the vegetation would be vulnerable to change if there is another fire within 50 years.
Monitoring	• Areas where change seems more likely – e.g. intense crown fire. • Monitor weed invasion, particularly at high altitude.

Question	Synthesis of workshop discussion and feed back
Rehabilitation options	**Action** • Targeted assistance with rainforest recovery may be warranted in highlands in order to manage fire at the landscape level, rainforests buffers soil moisture levels and create barriers to fire on days of non-catastrophic fire weather. • Slope stabilisation along Mersey Forest Rd. • No need to trial rehabilitation because silvicultural methods are well established. • If monitoring demonstrates any significant areas have failed to regenerate – consider application of aerially seeding, or other restoration techniques. • The ideal window for reseeding has already passed (immediate post-fire period) but could be attempted in first spring, or alternative restoration strategies could be undertaken in later years. **Focus** • Target seeding or planting in areas that require stabilisation, i.e. steep slopes; fire refuges; or areas that may assist reduce fire spread in more typical conditions; or for other landscape management reasons.
Rehabilitation priority	• Forests are a low priority for rehabilitation actions for this fire. • Forests may be a higher priority in other fire areas (e.g. Mawbanna, Wuthering Heights).
Research needs	• Determine the size/age of trees that are most vulnerable to being killed by fire under different fire severities, environmental situations.

3.7. Other issues

Background

Other issues discussed included impacts on fauna including animal welfare, weeds, water quality and quantity and sediment yield.

Animal welfare is often raised in the media in relation to bushfire as it was during and after the January 2016 fires. Members of the community are concerned that there may be suffering vertebrate animals as a result of a fire or that populations have been lost. During and post-fire the 2016 fires, fire crews and other workers/observers in the areas subject to fire did not observe/report any injured or dead vertebrate fauna. Simple monitoring using cameras and direct observation of animal sign was undertaken in the Lake Mackenzie area in both burnt and unburnt areas post-fire (Driessen unpublished report, 2016).

Casual observation has not noted a marked decrease in water quality. While bedload and saltating sediment loads may have increased, suspended sediments loads still appear to be low, even during moderate flood conditions. However, the effect of the major rain event in June has not yet been investigated.

There is likely to be insufficient gauge data to demonstrate a change in water discharge since the fire.

Weeds, such as thistles, have been observed among the early colonists around Lake McKenzie. John Morgan's group in Victoria have shown that weeds are appearing at higher elevations than previously (McDougall *et al*., 2005). It is likely that the proximity to farmland and the higher fertility of soils in this area have made it more vulnerable to weed invasion following fire than other areas of the TWWHA.

Fire impacts and response in weeds, animals and water quality – synthesis of workshop participant feedback

Box 7: Synthesis of workshop discussion for weeds, animals and water quality

Question	Synthesis of workshop discussion and feed back
Conservation importance	
Fire impact	• Thistles are likely to have a temporary increase, and will disappear without intervention with competition from native species. • Ragwort may attempt a significant range expansion in the burnt area.
Trajectory	• Survey and monitor weed invasion and manage where necessary. • Map unburnt islands and prioritise for fire protection. • Trial browsing exclosures.
Monitoring	• Remove weeds if monitoring/surveys suggests that there is a risk that they will become established.
Rehabilitation options	• Weed triage, particularly focused on ragwort control.
Rehabilitation priority	• Are mammal species using burnt montane vegetation following summer wildfire near Lake Mackenzie? • Do mammal invertebrate assemblages differ between burnt and unburnt area following summer wildlife in montane vegetation near Lake Mackenzie? • Methods of keeping further fire out of burnt areas • Cost effectiveness of prescribed burning

4. Priorities for action

The group discussed priority responses for managing the burnt area. There was a consensus that broad scale rehabilitation actions to mitigate fire damage are not justified by the impacts to conservation values in the Mersey Fire Complex in January. This was in part due to the relatively small proportion of any individual conservation value impacted by the fire, and also in some cases uncertainty as to what treatments might succeed in improving post fire outcomes.

Given the ongoing potential for future alpine fires, which may have a greater impact on sensitive conservation values, the group identified as a high priority using this fire to improve our understanding of how fire impacts important conservation values, and how land managers can respond to mitigate that damage. To this end, the group recommended that trials of rehabilitation techniques be run in selected areas. Also, the group recommended looking at the spatial distribution of fire impacts for all values, to improve our ability to predict fire impacts and identify naturally resilient areas.

Fire prevention is seen as more important than rehabilitation. Repeated fire with a short interval can cause ecosystem changing damage (Enright *et al*., 2015, McDougall *et a*l., 2015). In this environment, a second fire would undo any successes from active rehabilitation. The difficulty of preventing fire in the face of drought and lightning strikes was acknowledged. In order to better inform fire prevention efforts, it was suggested that examination of burning patterns in the recent fire and the 1960-61 fire could identify areas not impacted historically, which would be a priority for future protection. This may also help identify the characteristics of the most resilient parts of the landscape. Conservation values in these areas are the most likely to survive in the long term so should be a focus for protection.

To facilitate clear discussion, this workshop dealt with conservation values individually. In practice, it is better to look at an area within which those values occur and to treat it as an entire system. Given the importance of hydrology to many of the values identified as threatened, using small catchments as treatment units may be sensible.

The suitability of the Lake Mackenzie area for active management intervention was discussed. The group emphasised that management priority should be given to sites with the best chance of long term survival, given a future of climate change and further fire. The landscape context of the Lake Makenzie area combined with predicted climate change scenarios suggests that the likelihood of fire occurring in this area in the future is higher than some other areas and given limited resources it might be defensible in a triage situation to direct those resources to other areas.

The appropriateness of intensive management intervention in a World Heritage Area specifically identified for its wilderness values was also discussed. As the area around Lake Mackenzie has been impacted by this fire, the 1960-61 fire, hydro development and visitor impacts, its wilderness value is degraded. In this sense, it is an appropriate place to run rehabilitation trials. However, there remains the question of whether ‘natural’ erosion is preferable to active intervention to attempt to impose an ‘unnatural’ stability upon the environment. This question of how much active intervention is appropriate in a wilderness World Heritage Area is worthy of further research.

Summary of priorities

- No broad scale rehabilitation of fire damage is justified.
- Trials of rehabilitation techniques in burnt soils, sphagnum and pines are justified. Pool complexes should be included if monitoring shows fire initiated degradation is occurring.
- Monitoring of pool complexes should occur to identify any fire initiated degradation processes.
- Active weed management should occur.
- Research to identify targets for intense fire prevention work (historically unburnt areas, naturally resilient areas).
- Monitoring to improve understanding of how intensity of fire damage influences rate and degree of natural recovery.

5. Research needs — discussion session

The final session of the workshop was devoted to a discussion of the list of ongoing research needs originally presented in the report 'Fire regimes for nature conservation in the Tasmanian Wilderness World Heritage Area' (DPIPWE, 2015). Discussion focussed on identifying new ideas, rather than reviewing the existing list in detail. Also, topics raised here were those relevant to the management of the TWWHA as a whole, rather than the research topics raised in earlier sessions - fire impacts on alpine areas near Lake Mackenzie.

It is also worth noting that because of the emphasis of the workshop on alpine fire damage and rehabilitation, the makeup of the group at this year's meeting included mainly ecologists and fire managers. Climatologists and experts in fire behaviour were under-represented, and this may have biased the research needs discussed.

The research topics raised during the workshop are presented below. To put them in context of the earlier review, they have been added to the list presented in Section 6 of 'Fire regimes for nature conservation in the Tasmanian Wilderness World Heritage Area' (DPIPWE, 2015). New ideas are printed in red, and the previous text in black.

Research needs

(Reproduced from Section 6 of DPIPWE 2015 with additions from this workshop shown in red)

There are limitations to fire ecology knowledge and further research is required to improve the advice given to land managers. Listed here are a series of research questions raised in the review workshops or through the process of writing the report 'Fire regimes for nature conservation in the Tasmanian Wilderness World Heritage Area' (DPIPWE, 2015). Also included is the development of tools that could improve land managers ability to apply existing knowledge in a complex landscape.

It is recognised that this list of research tasks is well beyond that which could be achieved solely within DPIPWE. Ultimately, many other institutions need to be involved, including but not limited to the University of Tasmania, Forestry Tasmania, State Fire Management Council, Natural Resource Management bodies, other government agencies, the Bushfire and Natural Hazards Cooperative Research Centre, Emergency Services Council and others.

Note that to be easily applied to fire management, in particular to fire suppression in an emergency situation, the results of this research need to be presented as a map with associated guidelines.

Research tasks

1. Fire planning and execution tools:
   - 1.1. Fire planning information that does not require further research:
     - 1.1.1. Define fire regions based on fuel accumulation rates of dominant treatable fuels, the climate and elevation. They may also incorporate other influences on fire management such as cultural fire use by the Aboriginal community. Regions should also form realistic fire management blocks i.e. divided by natural fire boundaries e.g. large forest tracts.
     - 1.1.2. Identify moorland areas to be excluded from planned burning (i.e. not to be burnt on a regular short rotation).
     - 1.1.3. Map dry forest understory by structural/ floristic communities associated with different fuel hazard types and fire ecology e.g. shrubby, grassy, scrubby etc.
   - 1.2. Fire flammability and behaviour in fire sensitive communities (e.g. rainforest and mixed forest):
     - 1.2.1. Identify the threshold where rainforest becomes flammable.
     - 1.2.2. Develop a model for fire behaviour in rainforest.
   - 1.3. Moorland fuel accumulation rates and fire behaviour:
     - 1.3.1. Extend existing fuel accumulation and fire behaviour data set into sparse moorland on slopes.
     - 1.3.2. Develop a map of moorland fuel types either as a stand-alone map or as part of an integrated program to re-map moorland vegetation communities.
     - 1.3.3. Define a target post fire age distribution for sparse, low and moderate nutrient buttongrass moorland.
     - 1.3.4. Identify a minimum fire interval appropriate for sparse buttongrass on slopes.
   - 1.4. Fire modelling:
     - 1.4.1. Update Karen King's model (King, 2004) with better fuel hazard models.
     - 1.4.2. Investigate if there is a threshold level of fuel reduction burning above which it is practical to stop bushfire suppression activities. Alternatively, use a fire behaviour model to predict on a case by case basis.
     - 1.4.3. Use models of fire behaviour and projections of future fire risk to identify future fire refugia, which should be a priority for fire protection.
   - 1.5. Develop techniques to use remote sensing to map fire boundaries, intensities and within fire patchiness.
   - 1.6. Improve understanding of soil moisture and fire behavior:
     - 1.6.1. Collect real soil moisture data across a range of environments. Feed into 1.6.2.
     - 1.6.2. Develop more robust soil and fuel moisture models for a range of vegetation communities including moorland, grasslands and rainforest, combining a range of data inputs. Include identification of thresholds for safe and unsafe burning under prescribed burning and bushfire conditions, including reference to moisture thresholds below which soils become fuels.
     - 1.6.3. Improve understanding of the relationship between soil moisture, the flammability of rainforest and rainforest soils, and the likelihood of sustaining fire in rainforest.
     - 1.6.4. Investigate role of soil as a thermal and hydrological break on fire.

1.6.5. Improve understanding of organic soils as a fuel. Incorporate the influences of weather, soil moisture and fire conditions. Identify thresholds for moving from a smoldering to a flaming fire. Identify impact on root systems

1.6.6. Test the squeeze test of soil moisture and if necessary develop an alternative cheap and rapid assessment of soil moisture for field checking pre-fire.

1.7. Define reasonable and sustainable fire regimes in vegetation types other than moorlands:

1.7.1. Determine life history attributes and fire responses for a greater range of species and vegetation communities.

1.8. Impacts of fire suppression:

1.8.1. Investigate impacts of fire retardants and gels on flora, fauna and geomorphology.

1.8.2. Investigate effectiveness of retardants and gels at supressing fire during recent fire events.

1.8.3. Investigate impacts of using sea water to suppress fire on near coastal vegetation.

2. Fire behavior:

2.1. Complete a landscape scale analysis of lightning strikes.

2.1.1. Investigate role of landscape in determining strike point – e.g. geology, water content.

2.1.2. Investigate intervening in lightning patterns – lightning rods.

2.1.3. Install more lightning detectors in combination with weather stations.

2.2. Install more remote weather stations so that fire management decisions and behaviour prediction can be based on accurate weather data.

3. Investigate how to efficiently apply landscape scale monitoring and evaluation of fire impacts and fire management. Investigate using remote sensing with targeted surveys to validate.

4. Impacts of fire regimes and individual fires on values:

4.1. Mapping:

4.1.1. For priority areas, improve detail and accuracy of fire sensitive values maps to identify key areas for protection in an emergency fire suppression situation. Provide necessary interpretation and location digitally so that it is available to all emergency services.

4.2. Mosaics:

4.2.1. Identify is the best mosaic at the planned burn unit scale and at the landscape scale for maintaining natural values. Consider the important scale, which species are sensitive to local loss, and dispersal distances for sensitive species.

4.2.2. Investigate the effect of burn size on post-fire age mosaics.

4.3. Soils:

4.3.1. Investigate vulnerability of organic soils across different vegetation types to planned burn and bushfire, and to variations in fire frequency.

4.3.2. Identify conditions under which moorland vegetation can be burnt without inducing soil loss.

4.3.3. Investigate whether burning moorland under conditions that prevent soil loss still provides a reduction in bushfire risk.

4.3.4. Map the distribution of soils susceptible to fire related damage.

4.3.5. Identify and map high conservation value vulnerable soils (for input into the Bushfire Risk Assessment Model). Specify appropriate management zones for these areas.

4.3.6. Investigate any relationship between historical fire regime and soil depth/character.

4.3.7. Undertake dating to identify rates and timing of soil development and loss.

4.3.8. Investigate whether regular prescribed burning is associated with a smaller net loss of organic soils than losses associated with rare bushfires.

4.3.9. Identify landscape units that are inherently prone to fire and fire damage (classify using vegetation, aspect, wind exposure, slope steepness, soil type).

4.4. Soil invertebrates – investigate the relationship between diversity and post fire age.

4.5. Montane grassland biodiversity:

4.5.1. Investigate alternative ignition methods (including heli-torch), prescription burning conditions, and potential effectiveness of re-seeding.

4.5.2. Investigate how grassland burning affects fauna diversity.

4.5.3. Investigate the triggers that have promoted conversion of grasslands to sedgelands, woodlands or forest. Consider that trigger might be related to climate as well as fire.

4.6. Orange-bellied Parrots:

4.6.1. Investigate whether planned burning in moorland improves OBP food resources, including:

- Investigate spatial patterns of foraging.
- Investigate the relationship between post fire age and seed loads in moorland.

4.6.2. Investigate where planned burns for foraging habitat should occur relative to nesting habitat (ideally marginal to distant).

4.7. Investigate the response of Alkaline Pans to fire.

4.8. Investigate how to manage fire sensitive values in flammable landscapes (e.g. moorland soil, pencil pine in sedgy grasslands). Reliably low intensity fires are required to reduce fuel load without damaging values.

4.9. Compile a complete very long term fire history of the TWWHA using a range of data sources such as peat and lake cores, regolith profiles, and cave sediments.

4.10. Investigate the influence of fire on the spread of weeds, pests and diseases.

4.10.1. What is the combined impact of *Phytophthora* and fire on biodiversity.

4.10.2. What role does fire play in the spread of Devil facial tumour disease.

4.11. Maintain and expand collection of fire attribute data for different vegetation types

4.12. Impacts of fire management and response on wilderness.

4.12.1. Conduct social research into community tolerance of fire management and restoration activities in wilderness areas.

5. Research results:

5.1. Collate all research that has been done in the TWWHA to date.

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7. Appendices

Appendix 1: Workshop agenda

TWWHA Bushfire Research Group **Lake Mackenzie Alpine Fire Impacts Workshop** 8 June 2016 University of Tasmania		
8.30 am	*Coffee on arrival*	
9.00 am SHARP	Welcome and housekeeping	Peter Voller
	Workshop goals	Paul Black
	The Lake Mackenzie Bushfire: development and suppression efforts	Eddie Staier Alex Bradley
	Identifying rehabilitation priorities	Kath Storey
	Virtual field trip session 1	Kath Storey
10:30 am	*Morning tea*	
	Virtual field trip session 2	Kath Storey
12:30 pm	*Lunch*	
	Virtual field trip session 3	Kath Storey
	Fire research discussion	Paul Black / Adrian Pyrke
2:45 pm	*Afternoon tea*	
	Fire research discussion	Paul Black / Adrian Pyrke
	Overview	Paul Black
4:00 pm	*End of workshop*	

Appendix 2: TWWHA Bushfire Research Group 2016 Attendees

Surname	Name	Organisation	Field of interest, and geographical areas of interest
Allan	Kathy	Ecosystems and Forest Science University of Melbourne	• Dendrochronology/dendroclimatology • Predominantly Australasia
Balmer	Jayne	NVCB DPIPWE	• Flora values of the TWWHA • Tasmanian buttongrass moorland vegetation ecology • Tasmanian tall wet eucalypt forest vegetation ecology • Tasmanian alpine vegetation ecology
Barmuta	Leon	Biological Sciences UTAS	• Freshwater Ecology • Limnology of shallow lakes & wetlands, Tasmanian Central Plateau • Ecosystem processes in small streams and shallow lakes • Freshwater biodiversity • Design of surveys and experiments for biological impact assessment in freshwaters anywhere • Disturbance ecology anywhere • Regional effects of climate change on Tasmanian freshwater biota • Have postdoc who is fascinated by Black Carbon.
Black	Paul	Parks & Wildlife Service	• Fire Management • Incident response & management • Fire Risk assessment • Planned burning program development & implementation • State wide interest

Surname	Name	Organisation	Field of interest, and geographical areas of interest
Bowman	David	Biological Sciences UTAS	Interests • Fire ecology and management • Landscape ecology • Vegetation dynamics • Tree growth and climate • Fire and soils Geographic remit • Global, to local scales increasing focus on Tasmanian systems
Bradley	Alex	Tas Fire Service	• Fuel Reduction treatments, State-wide • Bushfire suppression activities, State-wide
Brooksbank	Neil	Tas Fire Service	• District Officer, Southern Region.
Buck	Rob	PWS DPIPWE	• Parks and reserves management
Comfort	Mike	NVCB DPIPWE	• Geoconservation values throughout the TWWHA and Tasmania • Natural area rehabilitation including alpine areas • Post fire assessment of January 2016 fires
Dean	Annette	PWS (previously Environment Tasmania and Nature Restoration Australia)	• Ecological restoration/ rehabilitation of logged coupes and roads in TWWHA • Community engagement/education in ecological restoration • Rehabilitation projects Gell River airstrips and Lake St Clair • Fire and soil erosion on the Central Plateau
Doyle	Richard	Tas Institute of Agriculture UTAS	• Soil science as based in earth sciences (geology) • Geomorphology and landscape evolution WRT soils • Land evaluation (capability and suitability) • Geo-archaeology • Food security and the future of food (mankind)
Driessen	Michael	NVCB DPIPWE	• Fauna conservation and fire research in the TWWHA especially in relation to buttongrass moorlands but also in other vegetation communities state-wide.

Surname	Name	Organisation	Field of interest, and geographical areas of interest
Dudgeon	Stuart	PWS	• Southern Region Fire Management Officer • Long association with managing Tasmania's reserves particularly managing impacts from visitation • Involvement in Fire behaviour prediction and response co-ordination • Fire impacts and impact prevention Role Prescribed burning can play in protecting fire sensitive vegetation and soils
Emms	Chris	PWS DPIPWE	• Land Management Practices • Natural, Cultural and Recreation Values Management • Project Management • Fire Management including Planned Burning, Wildfires, Fire Behaviour • Compliance and Enforcement • Central Plateau, Great Western Tiers, Walls of Jerusalem
Furland	James	UTAS	• Biometrics and Mathematical Modelling • Tasmanian wet forest fuel loads • Modelling alternative fuel management strategies
Graddon	Dave	Hydro Tasmania, Sustainable Resources Management	• Environmental Impact Assessment for renewable energy developments and Hydro operations and maintenance activities • Rehabilitation of Hydro construction sites • Natural values assessments • Soil erosion and weeds on the Central Plateau, Derwent and Gordon, Brumbys Creek • Wetland Restoration, Lagoon of Islands
Henry	Shasta	UTAS	• Invertebrate fauna
Kingdom	Denna	Tas Land Conservancy	• Science and practical implementation of fire management on land managed for conservation in Tas, including alpine and subalpine areas in the Central Highlands and NW Tas

Surname	Name	Organisation	Field of interest, and geographical areas of interest
Kratz	Svenja	Creative Exchange Institute (CxI) and Tasmanian College of the Arts (TCotA)	Expertise Art-Science Practice and Research (including public engagement with science through the creative arts) Context: Working on a curatorial project for *10 Days on the Island Festival* in 2017 on the theme of Fire that links to the 1967 and more recent bush fires in Tasmania including environmental implications.
Mendel	Louise	Tas Fire Service	• Vegetation ecology and management
Mitchell	Patrick	CSIRO Land and Water	• Forest and vegetation responses to drought and heat stress – plant ecophysiology, climatology, ecology • Drought and wildfire impacts on catchment and basin water use and water yield • Ecological risk assessment from mining impacts on regional hydrology • South west WA, Victorian foothill forests, Tasmanian plantations and east coast forests.
Moreton	Rob	NVCB DPIPWE	• State-wide: • Soil Survey/mapping- Soil Sampling and description • Land resource assessment • Hazard assessment- Acid Sulfate soil, erosion, salinity, waterlogging • Collation of Soil Legacy datasets • Sustainable Soil Management
Phillips	Michael	Tas Fire Service	• Divisional Commander and Deputy Operations Officer for a large duration of the Mersey Fire Complex. • Interested in practical outcomes for future fire management at the landscape level.
Prior	Lynda	UTAS Biological Sciences	• Tree growth • Flammability • Biogeography of fuels

Surname	Name	Organisation	Field of interest, and geographical areas of interest
Pyrke	Adrian	Eco Logical Australia	• Fire management planning, fuels, fire behaviour and fire risk assessment, Tasmania wide • Vegetation and fire ecology, Tasmania wide • Fire operations, incident control and planning
Rudman	Tim	NVCB, DPIPWE	• Plant disease management • Weed management • Fire planning
Sculthorpe	Andry	Tas Aboriginal Centre	• Fire and vegetation management
Staier	Edwin (Eddie)	PWS DPIPWE	Expertise • Reserve Management Practitioner • Planned Burning and Bushfire Practitioner • Fire Behaviour Analysis • Fire Ecology • Incident Management Teams Geographical interest • Northwest/West Coast • Inland Ranges and Plateaus Other related interests (Fire and reserve management) • Northern Australian Savannahs • Canadian West Coast Ranges.
Storey	Kathryn	NVCB DPIPWE	• Geoconservation values and fire throughout the TWWHA • Organic soil dynamics in buttongrass moorlands, mainly in SW • Fluvial geomorphology, mainly in SW • Fire and soil erosion on the Central Plateau
Styger	Jenny	UTAS	• Fire and vegetation interactions • Fire and rainforest • Climate change impacts on fire in western Tasmania

Surname	Name	Organisation	Field of interest, and geographical areas of interest
Summers	Steve	Consultant	• Fire and land management • Strategic fire planning • Fire behaviour and modelling • Geographic information systems • Incident management
Tapson	Natalie	RTBG DPIPWE	• Seed collection and seed-banking of Tasmanian species • Field Botany • Research into tissue culture and translocation of threatened species
Visoiu	Micah	NVCB DPIPWE	• Island (insular) Biogeography and Biogeography overall • General Tasmanian ecology • Working on TWWHA flora climate change monitoring program
Voller	Peter	NVCB DPIPWE	• Natural values conservation
Whinam	Jennie	Geography & Spatial Studies, UTAS, Aust Heritage Council, NRM South Board	• *Sphagnum* ecology - Australia and internationally (NZ, International Mire Conservation Group) • Sphagnum restoration after fire, moss harvesting and peat mining - Tasmania, Kosciuszko, Namadgi NPs, NZ • Flora conservation in the TWWWHA • Impacts of climate change on alpine ecosystems
Wild	Anita	Private consultant	• Applied ecology • Vegetation management and restoration
Wood	James	RTBG DPIPWE	• Seed conservation of native flora • Seed storage and longevity • Germination ecophysiology & seed dormancy • Field botany
Wren	Liz	PWS DPIPWE	• Media and Communications • Interest in fire ecology and alpine environment