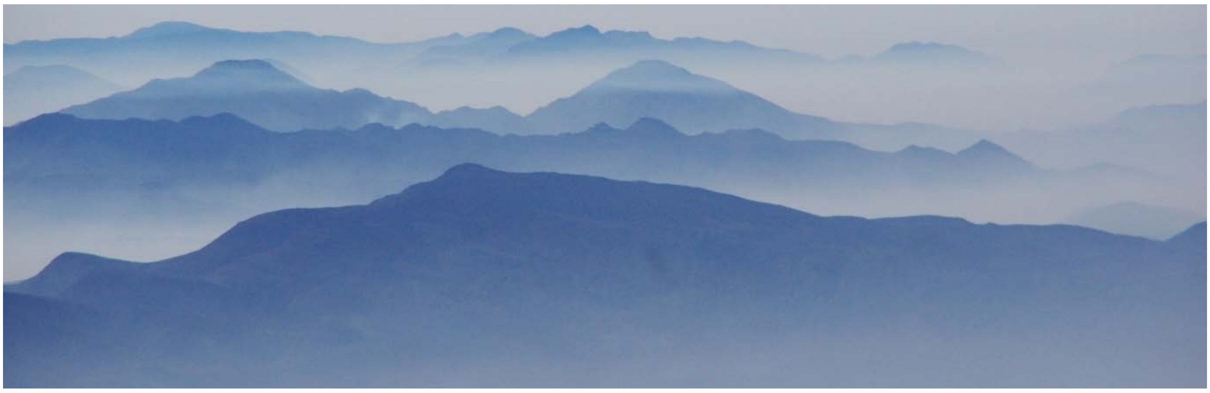

Lightning fires and climate change in the Tasmanian Wilderness World Heritage Area

Report prepared for:

Tasmanian Climate Change Office

Department of Premier and Cabinet,

Tasmania

By:

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Cover: looking east from Mt Propsting during the 2013 Giblin River fire.
All photographs in this report were taken by Jon Marsden-Smedley.

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1. Summary

1.1 Report aims and objectives

The main aims of this report are to review some of the implications of climate change on the vegetation and fire management of the Tasmanian Wilderness World Heritage Area (TWWHA) and the adjacent areas on its western boundary.

Fire has been a component of the area now covered by the TWWHA for thousands of years resulting in the development of a complex mosaic of fire-dependent and fire-sensitive vegetation types. This review indicates that in the TWWHA it is not operationally practical, ecologically desirable or economically possible to exclude fire. In order to manage and maintain world heritage values, it will be necessary to perform fire management operations in the region's fire-dependent vegetation such as buttongrass moorlands and native grasslands, along with fire exclusion in fire-sensitive vegetation such as alpine coniferous heaths and rainforests.

The report has four sections: aims and objectives including a review of background information; analysis of likely changes in fire patterns resulting from climate change; changes in lightning fire incidence over the past 35 years; discussion of the report's findings. In order to examine these issues, the TWWHA and its adjacent areas have been divided into five zones. In each of these zones, the fire history, vegetation type, soil type and climate change scenarios have been examined.

1.2 Changes in lightning fire incidence in the TWWHA

The occurrence of lightning fires in the TWWHA and adjacent areas has greatly increased over the past 45 years. During this time, lightning fires have gone from about 0.1% of fires and 0.01% of the area that was burnt, to about 28% of fires and 78% of the area that was burnt. Overall, nearly 60% of the areas that were burnt during this period by lightning fires consisted of buttongrass moorland, about 12% wet forest, 6% mixed forest and 6% rainforest. This increase in the incidence of lightning fires in the TWWHA has been particularly marked in the past 15 years, with major lightning caused fire seasons occurring in 2001, 2007, 2013 and 2016. Most of the area that was burnt by lightning fires between 1980/81 and 2015/16 was located in the Gordon - Franklin and West - South Coasts zones.

All of the recorded lightning fires between 1980/81 and 2015/16 were ignited in long unburnt vegetation. This indicates that it is highly probable that there is, at least in buttongrass moorland, an interaction between fire age and the potential for lightning to result in a sustaining fire. This interaction between fire age and the likelihood that lightning will result in a sustaining fire is probably due to smaller amounts of rain being required to extinguish fires in younger aged moorlands (which normally low density open fuel arrays) than is the situation in older moorlands (which normally have closed high density fuel arrays). This also indicates that planned burning in buttongrass moorlands, by resulting in more open fuel arrays, has the potential to significantly reduce the risk of lightning fires sustaining.

1.3 Climate change in the TWWHA between 1980 and 2100

The climate change parameters examined were Moorland Fire Danger Rating (MFDR), Forest Fire Danger Rating (FFDR), Soil Dryness Index (SDI), temperature, relative humidity (RH), wind speed, Moorland Fuel Moisture (Mf), Soil Dryness Index threshold (SDI T), Dry Periods (DP) and Lightning Potential (LP).

The climate change data indicates that between 1980 to 2100, only minor changes are expected to occur in wind speed, MFDR and RH, moderate increases are in FFDR and temperature along with minor decreases in Mf. In contrast, major increases are expected to occur in SDI, DP and SDI T, particularly in summer and autumn. The LP is expected to initially increase, and then decrease.

This means that the major impacts expected to occur from climate change are related to changes in vegetation and soil flammability resulting from increases in the SDI, Dry Periods and SDI Thresholds. These increases in soil dryness are likely to be already occurring (ie within the 2010 to 2030 time period) as an increased number of lighting ignitions, increased size of the areas burnt along with increased occurrence of fires in organosols (ie peat fires in organic soils). These increases in peat fire occurrence will also mean that the costs and resources required for wildfire suppression will also increase.

At the current time in Tasmania, the relationships between organosol type and their potential to burn are very poorly understood. From the information that is available, the critical factors determining the potential for peat fires to occur are related to the organosol type along with its organic and moisture contents. This means that the organosols most at risk are probably those which have high levels of organic matter and are located in areas that were in the past (ie pre climate change), too wet to sustain burning.

Within the TWWHA and adjacent areas, the region’s land manager, the PWS, conducts extensive buttongrass moorland planned burning in both spring and autumn when the region’s soil and meteorological conditions are suitable. The main aims of this planned burning are to reduce wildfire risk and maintain fire dependent communities. Under the current climate, the conditions suitable for conducting safe and effective buttongrass moorland planned burning occur more frequently in autumn than in spring. The increases in autumn of SDI, Dry Periods and SDI Thresholds will mean that buttongrass moorland planned burning in autumn is highly likely to be adversely impacted. These impacts will mainly result from the wet scrub which is normally adjacent to buttongrass moorlands being dry enough to sustain burning throughout autumn and hence not being suitable for use as a fire control boundary.

Whilst over the past about 35 years some areas of fire-senstive alpine coniferous heath, coniferous rainforest and rainforest have been burnt in the TWWHA and adjacent areas, these burnt areas are far smaller than have occurred in the preceding 100 years. The post fire recovery times indicate that the area of coniferous alpine heath and rainforest will be reduced if fires average more than about 0.1 to 0.2% of the vegetation’s area per year. In the case of rainforest, the area of rainforest will be reduced in fires average more than about 1% of the rainforest’s area per year. During the period 1980/81 to 2015/16, fires averaged about 0.01% of coniferous alpine heath, about 0.05% of coniferous rainforest and about 0.6% of rainforest per year. Whilst significant, these areas are less than the vegetation’s potential post fire recovery rates (and far lower than those that occurred during the preceding about 100 years).

2. Report aims and objectives

2.1 Introduction

The main aims of this report are to review the implications of climate change on the vegetation and fire management of the Tasmanian Wilderness World Heritage Area (TWWHA) and the adjacent areas on its western boundary.

This report has four main sections. This section reviews background information. The next two sections provide an analysis of changes in lightning fire incidence over the past 45 years and an analysis of the likely changes in fire patterns resulting from climate change. Finally, the last section discusses the implications arising from the findings in this report.

In order to perform these analyses, this report provides a breakdown of the distribution of different vegetation types in the TWWHA, an assessment of the likely changes in vegetation flammability resulting from climate change and reviews the lightning fire history of the region.

The climate change data has been derived from the climate change scenarios generated by *The Climate Futures for Tasmania Future Fire Danger Project* undertaken by the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC). This data has been derived from the high quality, fine-scale climate projections generated by the ACE CRC's Climate Futures for Tasmania project which aimed to increase the understanding of bushfire meteorology, fire danger hazards and fire risks in a changing climate (see Love et al. 2016a, 2016b).

The geographic area covered by this analysis is the TWWHA and the adjacent areas that are located on its western boundary (Figure 1).

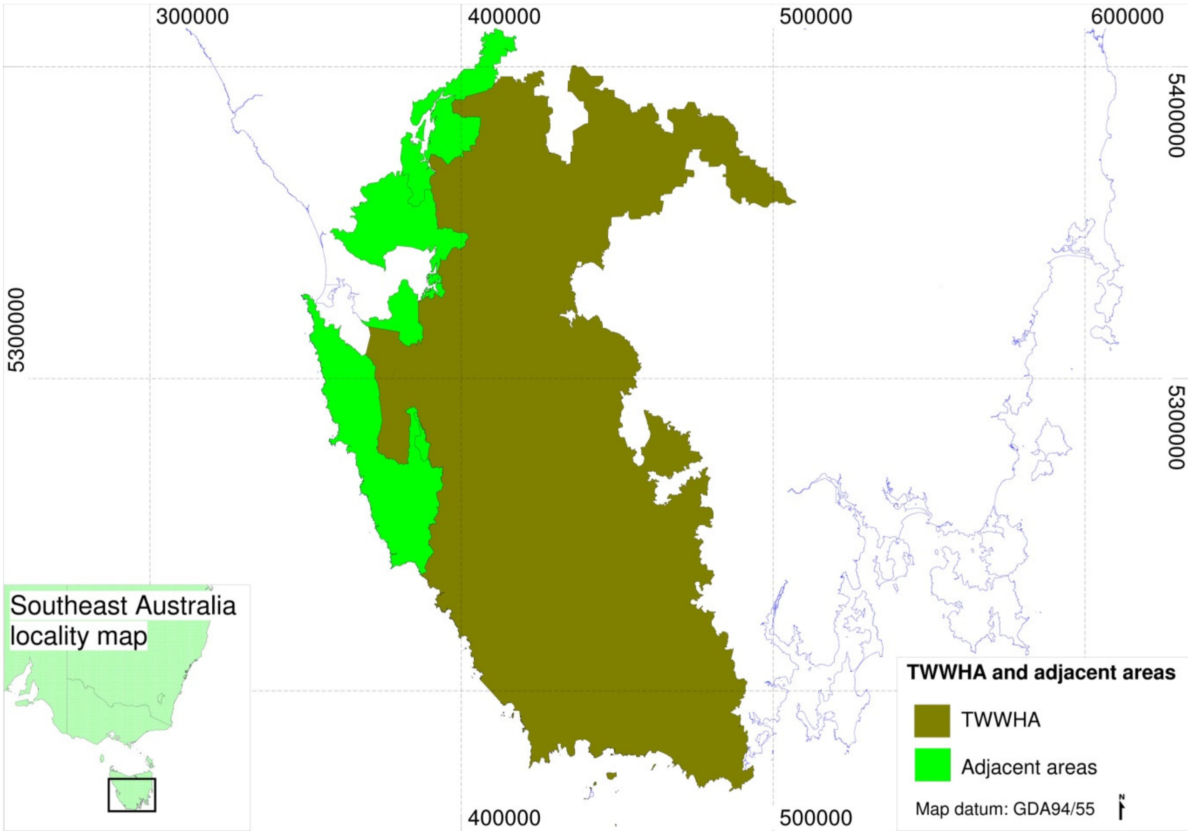


Figure 1. TWWHA locality map.

2.2 Fire history of the TWWHA

Fire has been a component of the environment of the region now covered by the TWWHA for millennium.

Anthropological and paleobotanical evidence indicates humans have occupied Tasmania for at least the last 35 000 years (Kee et al. 1993) and possibly as much as 70 000 years (Jackson 1999). During this period, burning by Aboriginal people and possibly lightning along with variation in topography, soil fertility and site productivity has resulted in the development of a complex mosaic of vegetation types (DPIPWE 2016).

Prior to European settlement, the available evidence strongly suggests that Aboriginal people were actively managing fire and performing burns in buttongrass moorlands and grasslands, mostly when wet scrub, wet eucalypt forest, mixed forest, rainforest and alpine areas were too wet to burn. This regime of active fire management would have resulted in frequent fires in buttongrass moorlands and grasslands, relatively infrequent fires in scrub and eucalypt forest and very few fires in rainforest and alpine areas (Marsden-Smedley 1998; Marsden-Smedley and Kirkpatrick 2000). The available evidence also indicates that very large fires periodically occurred in what is now the TWWHA during the period of Aboriginal management. These very extensive, landscape scale fires burnt the majority of what is now the TWWHA with these landscape scale fires occurring in about the 1550s and 1790s (Marsden-Smedley unpublished data).

Following the forced removal of Aboriginal people from the region, the fire regime changed to a regime of few fires followed by a massive fire. The available evidence indicates that three such cycles have occurred since the 1830s. This means that there were probably relatively few fires in the period between the 1830s and the major fires of about 1850/51 (which were probably lit by Colonial Office survey parties). There were then few fires until the massive fires of 1897/98 when over half of the area now covered by the TWWHA burnt (along with probably a third of Tasmania). There were then few fires until the very large fires in 1933/34 when over a third of the TWWHA burnt. Finally, with the exception of the extensive 1960/61 Central Plateau fire there were relatively few fires in the TWWHA between the 1930s and the 1970s (Marsden-Smedley 1998; Johnston and Marsden-Smedley 2001).

This means that, by the about 1980, much of the area that is now included within the TWWHA had not been burnt since the 1933/34 fire resulting in the majority of the TWWHA's buttongrass moorland being long unburnt and hence, old growth.

Starting in the early 1990s, there was a growing realisation of the TWWHA's fire regime and the requirement for periodic burning to maintain ecological values and reduce fuel hazards. This led to the development of fire management strategies aiming to perform planned burning in the region's fire-dependent buttongrass moorlands and grasslands and to a lesser extent low altitude heathlands, wet scrub and eucalypt forests along with fire exclusion in rainforests and alpine areas. This requirement for enhanced fire management resulted in the Parks and Wildlife Service (PWS) leading the development of a range of fire management systems, particularly for buttongrass moorlands.

Leading on from this, since the early 1990s the PWS has increased its usage of planned burning in buttongrass moorlands and grasslands to manage the level of fuel hazard and to maintain species diversity.

2.3 Fire-attributes vegetation types in the TWWHA and adjacent areas

The vegetation of the TWWHA has been mapped by the TasVeg mapping program (DPIPWE 2016).

The vegetation map produced by the TasVeg mapping program is highly complex, identifies 156 different vegetation types and is of variable accuracy. The TasVeg map was also not designed for fire management purposes.

As a result, Pyrke and Marsden-Smedley (2005) developed a methodology for reclassifying the TasVeg map for fire management purposes into its fire-attributes types and assigning fire sensitivities and flammabilities to the different polygons. This reclassification also had the advantage that by amalgamating many of the TasVeg mapped vegetation types, it greatly simplified the map and increased the map's accuracy and reliability.

The current version of the TasVeg map, TasVeg3, has been reclassified into its fire-attributes vegetation types, fire sensitivities and flammabilities using the methodology described by Pyrke and Marsden-Smedley (2005). The fire-attributes vegetation types occurring within the TWWHA and its adjacent areas are summarised in Table 1.

Table 1. Fire-attributes vegetation types within the TWWHA and adjacent areas.

Fire-attributes vegetation code and type		Fire sensitivity	Flammability
Ac	Alpine/subalpine coniferous heathland	E	L to M
As	Alpine/subalpine heathland	M to VH	L to M
Ag	Alpine/subalpine sedgy and grassy	M	H
Sp	Sphagnum	H	L
Bs	Buttongrass moorland	L	VH
Df	Dry forest	L to E	M to H
Dd	Dry woodland	L to E	M to H
Dp	Damp sclerophyll forest	M	M
Hh	Heathland	L to VH	H to VH
Ds	Dry scrub	L to VH	H to VH
Ws	Wet scrub	L to M	H
Wf, Wd	Wet sclerophyll forest and woodland	H	M
Mf	Mixed forest	VH	L to M
Rf	Rainforest	H to E	L
Rc	Coniferous rainforest	H to E	L
Gr	Native grassland	L	H
Pt	Agricultural land	L	M
Sr	Plantation	E	M
Wl	Swamp and wetland	L	L to H
Zz	Unvegetated	NA	NA

Note: based on the methodology of Pyrke and Marsden-Smedley 2005; see also Marsden-Smedley 2009; L = low, M = moderate, H = high, VH = very high, E = extreme, NA = not applicable.

2.4 Zones in the TWWHA and adjacent areas

At over 1.8 million hectares, and over 200 by 100 kilometres in size, the TWWHA contains a very wide range of habitats and vegetation types.

In order to address this issue, the TWWHA and the adjacent areas on its western boundary were subjectively divided into five zones on the basis of their predominant fire-attributes vegetation type, river catchments, topography, average altitude, geology and distance from the coast (Figure 2; Table 2).

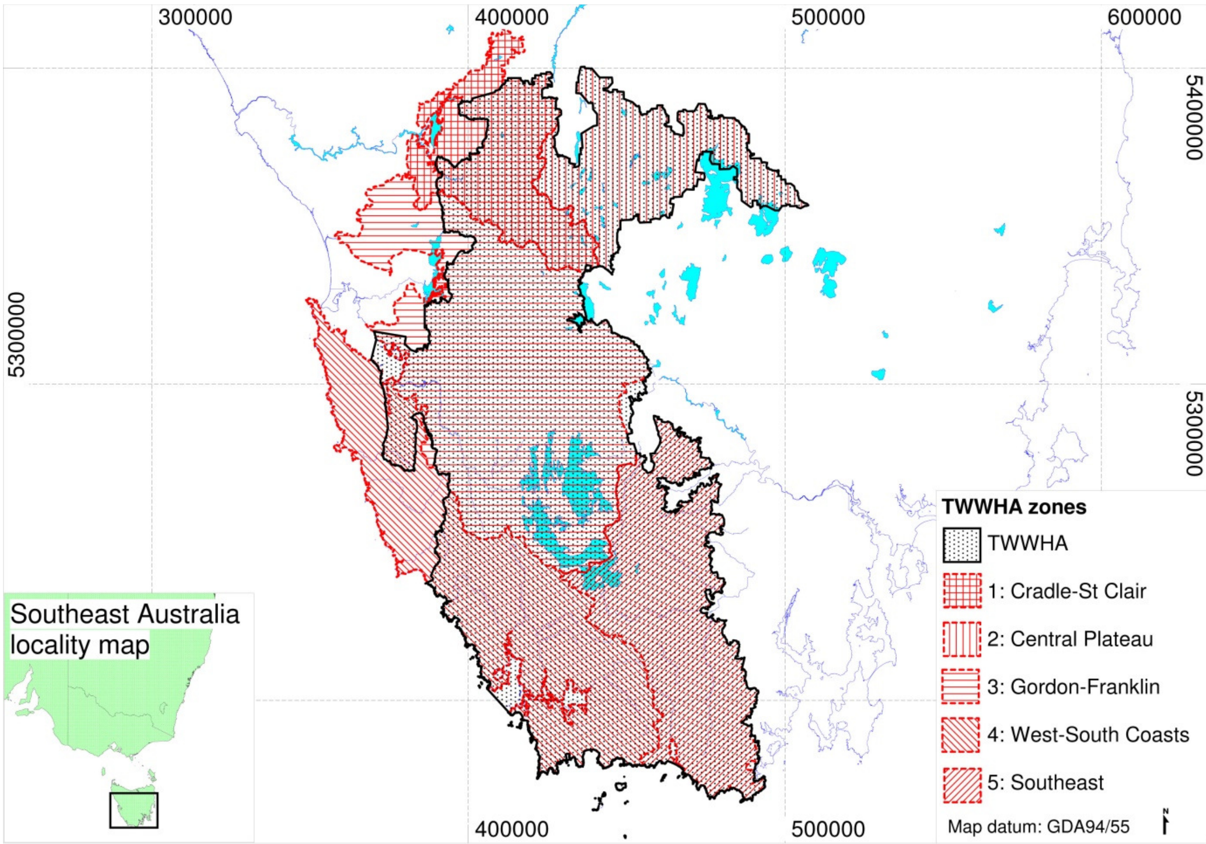


Figure 2. TWWHA and adjacent area zones.

The areas of the different fire-attributes vegetation types, topography vary greatly between the different zones (Table 2). The largest proportion of rainforest is the Cradle-St Clair, Gordon - Franklin and Southeast zones, the largest proportion of wet eucalypt forest is in the Cradle-St Clair, Central Plateau and Southeast zones, while the largest proportion of buttongrass moorland is in the West - South Coasts zone.

For example, the Cradle-St Clair zone consists of most of Tasmania's highest mountains which are surrounded by extensive moorlands and deep dissected valleys covered by wet forest, mixed forest and rainforest. The Central Plateau zone consists of extensive wet eucalypt forests and rainforests along the Great Western Tiers, surrounding the high plateau surface which is covered by alpine heathlands, alpine grasslands and subalpine woodlands. The western half of the Gordon - Franklin zone consists of the rainforest and wet eucalypt forest dominated Gordon and Franklin River valleys while the zone's eastern half is dominated by buttongrass moorland and wet scrub covered plains and hills. The West - South Coasts zone is dominated by extensive plains and hills covered by buttongrass moorlands, along with smaller areas of wet scrub, wet eucalypt forest and rainforest. Finally, the

Southeast zone consists of complex topography dominated by rainforests and wet eucalypt forests with smaller areas of buttongrass moorland in some of the larger valleys (Table 2).

Table 2. Area of fire-attributes vegetation type in different zones.

	1: Cradle-St Clair		2: Central Plateau		3: Gordon-Franklin		4: West - South Coasts		5: Southeast		Entire region	
type	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
Ac	10150.1	4.9	19816.7	10.1	3157.7	0.5	653.3	0.1	5213.8	1.6	38991.6	2.2
Ag	6895.4	3.3	36138.4	18.3	4687.5	0.8	875.8	0.2	4928.0	1.5	53525.1	3.0
As	8242.0	4.0	28430.5	14.4	12812.5	2.1	3679.1	0.8	10792.0	3.2	63956.2	3.6
Bs	22169.9	10.6	548.7	0.3	135935.8	22.7	234605.6	51.5	36995.4	11.0	430255.4	24.0
Df	5976.3	2.9	23383.1	11.9	18216.7	3.0	508.3	0.1	13037.1	3.9	61121.5	3.4
Dp	1635.3	0.8	4683.7	2.4	3391.6	0.6	0.0	0.0	0.0	0.0	9710.6	0.5
Ds	40.1	0.0	7.5	0.0	270.6	0.0	2648.2	0.6	453.9	0.1	3420.4	0.2
Gr	0.3	0.0	10.6	0.0	0.0	0.0	239.8	0.1	52.5	0.0	303.3	0.0
Hh	2.8	0.0	0.0	0.0	1.7	0.0	92.0	0.0	67.0	0.0	163.6	0.0
Mf	22953.5	11.0	4149.7	2.1	72087.2	12.1	29540.3	6.5	49104.2	14.6	177835.0	9.9
Pt	0.8	0.0	1098.6	0.6	6.1	0.0	0.0	0.0	44.0	0.0	1149.5	0.1
Rc	23398.1	11.2	1608.9	0.8	39421.8	6.6	5402.5	1.2	19545.8	5.8	89377.1	5.0
Rf	25285.2	12.1	5066.4	2.6	136548.3	22.8	74842.9	16.4	70238.3	20.9	311981.0	17.4
Sp	673.5	0.3	1984.9	1.0	66.7	0.0	0.0	0.0	51.9	0.0	2777.0	0.2
Sr	94.8	0.0	469.0	0.2	3.8	0.0	0.0	0.0	943.1	0.3	1510.6	0.1
We	0.0	0.0	1.5	0.0	2.8	0.0	32.4	0.0	0.0	0.0	36.7	0.0
Wf, Wd	59911.7	28.8	66297.4	33.6	94878.0	15.9	40679.1	8.9	80158.5	23.8	341924.7	19.1
Wl	54.0	0.0	76.6	0.0	10.6	0.0		0.0	129.4	0.0	270.6	0.0
Ws	19530.1	9.4	858.4	0.4	73587.9	12.3	60233.4	13.2	43182.0	12.8	197391.8	11.0
Zz	1244.0	0.6	2408.3	1.2	2610.3	0.4	1534.2	0.3	1336.3	0.4	9133.1	0.5
Total	208258.1		197038.9		597697.5		455566.9		336273.2		1794834.5	
%	11.6		11.0		33.3		25.4		18.7			

Note: areas covered by water have not been included in Table 2.

Note that it is probable that the area of coniferous alpine heath and coniferous rainforest has been over estimated by the TasVeg3 map resulting in over estimates of the area of these vegetation types in the fire-attributes vegetation map.

There is considerable variation in organosol (ie organic soil) type, structure and degree of humidification in the TWWHA's different vegetation associations (di Folco 2007). Peat soils are a form of organosol where the organic content exceeds 30%. The main peat types are fibric, hemic and sapric peat. Fibric peat is the least humified and comprises partly decomposed material, with the leaves, twigs, roots and bark making up the soil still being recognisable. The least humified type of fibric peat is duff, which typically occurs on the soil surface. Hemic peat consists of moderately to well humified material with the material making up the peat not being recognisable. Sapric peat is the most highly humified with the peat's constituent components having fully broken down into a fine grained, structure-less material (Isbell 2002). These differences in peat type strongly influence the soil's potential to sustain burning.

Observations by the author over the past about 30 years indicates that peat fires are more common in sites with fibric soil and duff (particularly those underlying wet scrub) than other peat types and that few peat fires occur in sites with sapric peat soils.

2.5 Vegetation and soil flammability

The issue of the flammability of the different vegetation and soil types in lowland areas western and southwestern Tasmania is at the present time, poorly understood. As a result, there is a high degree of uncertainty regarding predictions of vegetation flammability under different conditions and of the thresholds between non-sustaining and sustaining fires.

To date, the only quantified work examining vegetation flammability has been performed in buttongrass moorlands and native grasslands. This work resulted in the development of models which use the prevailing weather and fuel to predict the thresholds between non-sustaining and sustaining fires (Marsden-Smedley et al. 2001; Leonard 2009).

In addition, over the past about 40 years fire practitioners (particularly those based in the forest industry) have made a large number of observations regarding the relationships between the Soil Dryness Index (SDI; Mount 1972) and the potential for different vegetation and soil types to sustain burning.

The SDI estimates the amount of rainfall required to saturate the soil profile and includes estimates of the effective rainfall once the effects of vegetation interception, runoff and evapotranspiration have been taken into account. Due to its simplicity and small number of inputs used, the SDI is operationally practical and easy to use but the SDI is also prone to errors, needs to be used with caution and anchored by field data. The major concerns with the SDI relate to its assumptions regarding rainfall interception, energy budget, location of its prediction sites and the requirement to extrapolate the predicted SDI to field locations. Note that the issue of poor performance by the SDI is currently being addressed by the Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC) who are developing a new Australian Soil Moisture Information system (JASMIN: Dharssi and Kumar 2016) which should be operationally available within the next five years.

This means that at the present time the SDI is the most robust and easily utilised methodology available for predicting vegetation and soil flammability in Tasmania. This knowledge regarding the interactions between the SDI of the potential for different vegetation and soil types to sustain burning has been summarised in Marsden-Smedley et al. (1999), FT (2005a, 2005b), Marsden-Smedley (2009), Styger (2014, 2015) and Table 3.

Table 3. Vegetation and soil flammability in lowland western and southwestern Tasmania.

	Buttongrass moorland		Native grassland		Wet scrub		Wet forest and woodland		Mixed forest		Rainforest	
SDI	Veg	Soil	Veg	Soil	Veg	Soil	Veg	Soil	Veg	Soil	Veg	Soil
0 to 10	H	L	L	VL	VL	VL	VL	VL	NF	NF	NF	NF
11 to 15	VH	M	M	L	L	VL	VL	VL	VL	NF	NF	NF
16 to 25	VH	H	H	M	H	M	M	L	L	L	VL	VL
26 to 50	VH	H	VH	H	H	H	H	H	M	M	L	L
>50	VH	VH	VH	VH	VH	VH	VH	VH	VH	VH	H	H

Note: table summarised from Marsden-Smedley et al. (1999); FT (2005a, 2005b); Marsden-Smedley (2009); VL = very low, L = low, M = moderate, H = high, VH = very high, E = extreme, NF = not flammable.

In subalpine and alpine areas, there is less information available and hence, a higher degree of uncertainty regarding the issue of vegetation and soil flammability at different SDI levels. This means that it is not possible to use the SDI to make reliable predictions as to when these vegetation and soil types will sustain burning.

2.6 Analysis of fire records between 1980 and 2016

For the period 1980/81 to 2015/16, this report has reviewed the cause and areas burnt for all fires in the PWS fire history data base that occurred within the TWWHA and adjacent areas (Figure 2). The data for all of the recorded fires in each fire season (July to June) between 1980/81 and 2014/15 was grouped into five year blocks with the data recorded during the 2015/16 fire season being kept separate.

For the time period 1980/81 to 2004/05, this review of fire cause and areas burnt involved aerial observation and/or on-the-ground checking of all burnt areas (see Marsden-Smedley 1998; Johnston and Marsden-Smedley 2001; Marsden-Smedley unpublished data). Note that this means that the fire cause recorded for some fires in the PWS fire history database have been reclassified in this analysis.

In addition, records of abandoned campfires burning less than 10 m^2 were not included in this analysis (almost all of which were recorded from the vicinity of Cockle Creek).

For the period 2005/06 to 2015/16, the PWS has kept highly detailed records of fire cause and areas burnt, including recording fire ignitions from lightning tracking systems such as those run by Global Position and Tracking Systems (GPATS).

The fire cause, number of fires, areas burnt and average fire sizes in different periods are shown in Table 4.

Table 4. Recorded fires in the TWWHA and adjacent areas between 1980/81 and 2015/16.

	1980/81 to 1984/85	1985/86 to 1989/90	1990/91 to 1994/95	1995/96 to 1999/00	2000/01 to 2004/05	2005/06 to 2009/10	2010/11 to 2014/15	2015/16	Total
Arson									
Number	22	24	23	18	15	14	16	0	132
Area	15144.0	37979.2	1360.6	1001.6	6450.1	269.8	2250.2	0.0	64455.5
Av size	688.4	1582.5	59.2	55.6	430.0	19.3	140.6	0.0	488.3
Escaped campfires and stoves									
Number	3	2	5	0	1	10	31	0	52
Area	7921.7	86.3	456.7	0.0	0.2	5.0	0.1	0.0	8470.0
Av size	2640.6	43.1	91.3	0.0	0.2	0.5	0.0	0.0	162.9
Escaped management burns									
Number	1	5	0	2	1	1	1	0	11
Area	1763.9	41849.6	0.0	5412.8	4729.9	429.5	1.2	0.0	54186.9
Av size	1763.9	8369.9	0.0	2706.4	4729.9	429.5	1.2	0.0	4926.1
Lightning									
Number	10	3	4	6	21	33	9	18	104
Area	1089.1	1177.7	123.9	298.5	2747.8	53991.7	40733.2	21897.2	122059.1
Ave size	108.9	392.6	31.0	49.8	130.8	1636.1	4525.9	1216.5	1173.6
Planned burns									
Number	10	9	9	22	37	52	27	0	166
Area	9904.4	1506.3	794.1	3522.7	9767.0	10976.7	18102.7	0.0	54573.9
Av size	990.4	167.4	88.2	160.1	264.0	211.1	670.5	0.0	328.8
Misc									
Number	2	5	4	0	4	5	1	0	21
Area	157.3	3018.8	158.6	0.0	2829.1	7.0	0.2	0.0	6171.0
Av size	78.6	603.8	0.0	0.0	707.3	1.4	0.2	0.0	293.9
Total, all fire types									
Number	48	48	45	48	79	115	85	18	486
Area	35980.4	85617.9	2893.9	10235.6	26524.1	65679.7	61087.6	21897.2	309916.4
Av size	6270.8	11159.3	269.7	2971.9	6262.2	2297.9	5338.4	1216.5	637.7

2.7 Analysis of climate change data

The Climate Futures Tasmania (CFT) data for the TWWHA was calculated using the A2 climate change scenario and analysed for four time periods:

- recent past 1980 to 2000;
- current and near future 2010 to 2030;
- mid-century 2040 to 2060;
- end-century 2080 to 2100.

For each day in CFT data, the 18:00 hours data was averaged for each of the parameters in each of the time periods (see Love et al. 2016a, 2016b).

The domain used for calculating the climate change data was restricted to the area covered by the TWWHA, as shown in Figure 3.

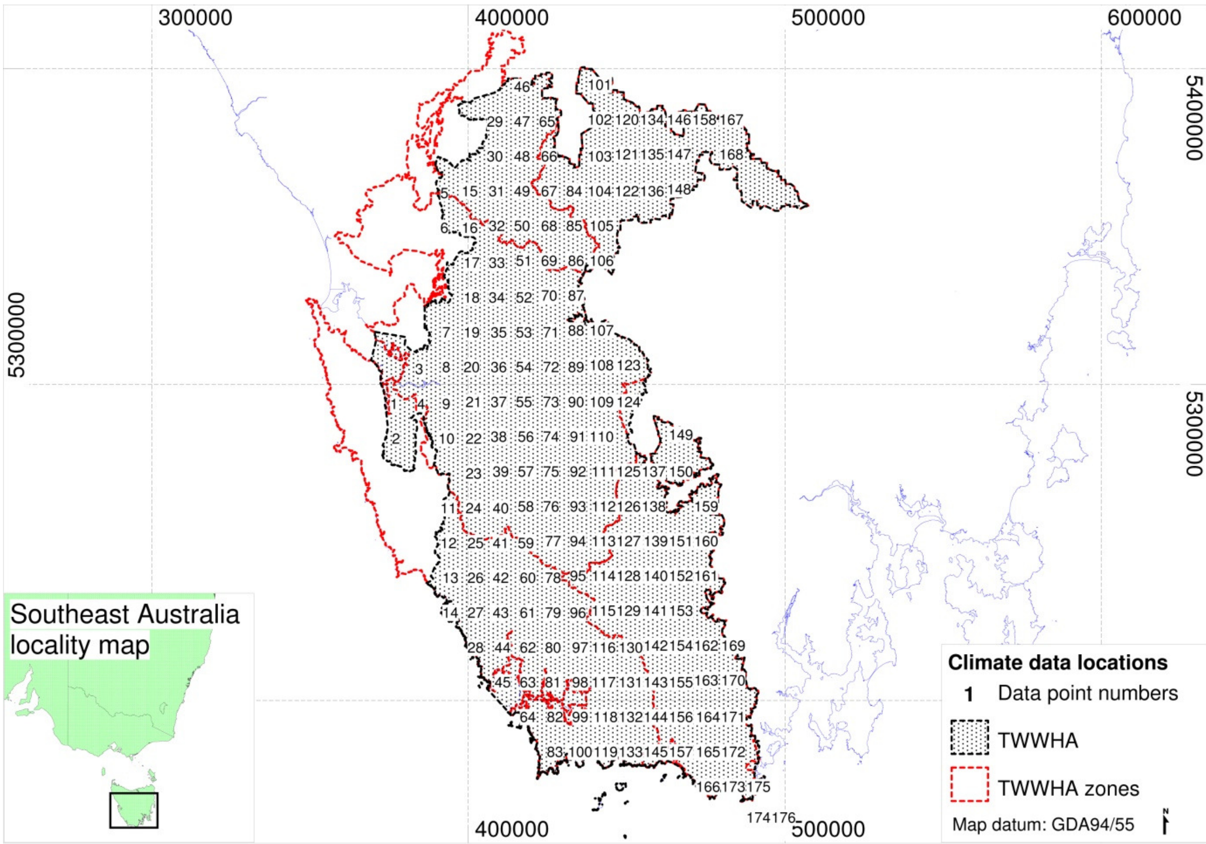


Figure 3. Locations used for calculating climate change data.

For each of the 176 data points within the TWWHA, the following data parameters, percentiles and data were calculated:

Parameter		Percentiles and data calculated
MFDR	Moorland Fire Danger Rating	85, 90, 95, 99, 99.5, 99.9;
FFDR	Forest Fire Danger Rating	85, 90, 95, 99, 99.5, 99.9;
SDI	Soil Dryness Index	85, 90, 95, 99, 99.5, 99.9;
T	temperature, °C	85, 90, 95, 99, 99.5, 99.9;
RH	relative humidity, %	15, 10, 5, 1, 0.5, 0.1;
Wind	wind speed, km/hr	85, 90, 95, 99, 99.5, 99.9
MF	Moorland Fuel Moisture, %	15, 10, 5, 1, 0.5, 0.1;
SDI T	Soil Dryness Index Thresholds	days per month with SDI >50 in each time period;
DP	Dry Periods	days per month with <50 mm of rain in each time period;
LP	Lightning Potential	days per month in each time period.

The Moorland Fire Danger Rating (MFDR) was calculated using the methodology in Marsden-Smedley (1993) and Marsden-Smedley et al. (1999). The Moorland Fuel Moisture (Mf) was calculated using the methodology in Marsden-Smedley and Catchpole (2001) and Marsden-Smedley et al. (1999).

The Forest Fire Danger Rating (FFDR) was calculated using the methodology in McArthur (1962, 1967, 1973) and using the formulas in Noble et al. (1980).

The SDI Threshold (SDI T) was calculated as the number of days per month in each time period where the SDI was greater than 50. The rationale for using this threshold is detailed in Section 2.5.

The Dry period (DP) data was calculated as the number of days per month in each time period where the rainfall in the proceeding 30 days was less than 50 mm. The rationale for using this threshold is detailed in Styger (2014) and Styger and Kirkpatrick (2015).

The dry Lightning Potential (LP) was calculated as the number of days per month in each time period using the methodology developed by Rorig and Ferguson (1999), together with the use of modest upward vertical motion (as operationally implemented in the Australian Bureau of Meteorology National Thunderstorm Forecast Guidance System; Deslandes et al. 2008; Fox-Hughes 2016; Love et al. 2016a, 2016b).

3. Changes in lightning fire incidence in the TWWHA

3.1 Lightning fires in the TWWHA and adjacent areas between 1980 and 2016

There is very strong anecdotal evidence for marked increases in lightning fire incidence in western and southwestern Tasmania over the past 45 years.

Research conducted in the 1970s indicated that in southwest Tasmania, lightning fires were only responsible for about 0.1% of fires and about 0.01% of the area burnt (Bowman and Jackson 1981). Subsequent research conducted by the author of this report indicates that the estimates of lightning fire incidence made by Bowman and Jackson (1981) are realistic. This review of past fires in the TWWHA and adjacent areas involved searching for fire scars on all of the approximately 7 000 aerial photographs in the DPIPWE historical aerial photograph collection that were taken prior to the 1980s and cover the TWWHA and its adjacent areas. In addition, assessments of all recorded fires in the PWS fire history database, extensive aerial surveys and the recording of fire history information at over 2 500 field sites has been performed (Marsden-Smedley 1998; Johnston and Marsden-Smedley 2001; Marsden-Smedley unpublished data).

Throughout the period between the 1980s and 1990s, while there were frequent anecdotal observations of lightning storms (eg Figure 4), few sustaining fires were recorded (Marsden-Smedley 1998; Johnston and Marsden-Smedley 2001; PWS unpublished fire history database).

Figure 4. Thunder storm in the Cradle Mountain-Lk St Clair National Park in the late 1990s.

Starting in the early 1980s, fire history records were collected by the PWS and Forestry Tasmania. All of the fires that occurred between 1980/81 and 2004/05 have been reviewed by the author and the fire's likely ignition cause determined. Since about 2005/06, the PWS has kept detailed records of fire cause in the area covered by this report (Marsden-Smedley 1998; Johnston and Marsden-Smedley 2001; PWS unpublished fire history database).

During the time period between 1980 and 2015/16 there has been a marked increase in both the number and size of lightning fires in the TWWHA and its associated areas. This increase in the incidence of lightning fires in the TWWHA has been particularly marked in the past 15 years, with major lightning caused fire seasons occurring in 2001, 2007, 2013 and 2016 (PWS fire history database).

When the lightning fire records were analysed the entire fire footprint was included. These increases in number and size have resulted in a marked increase in the areas impacted by lightning fires. The areas burnt within the TWWHA and adjacent areas in the period 1980/81 to 2015/16 are shown in Figures 5 and 6.

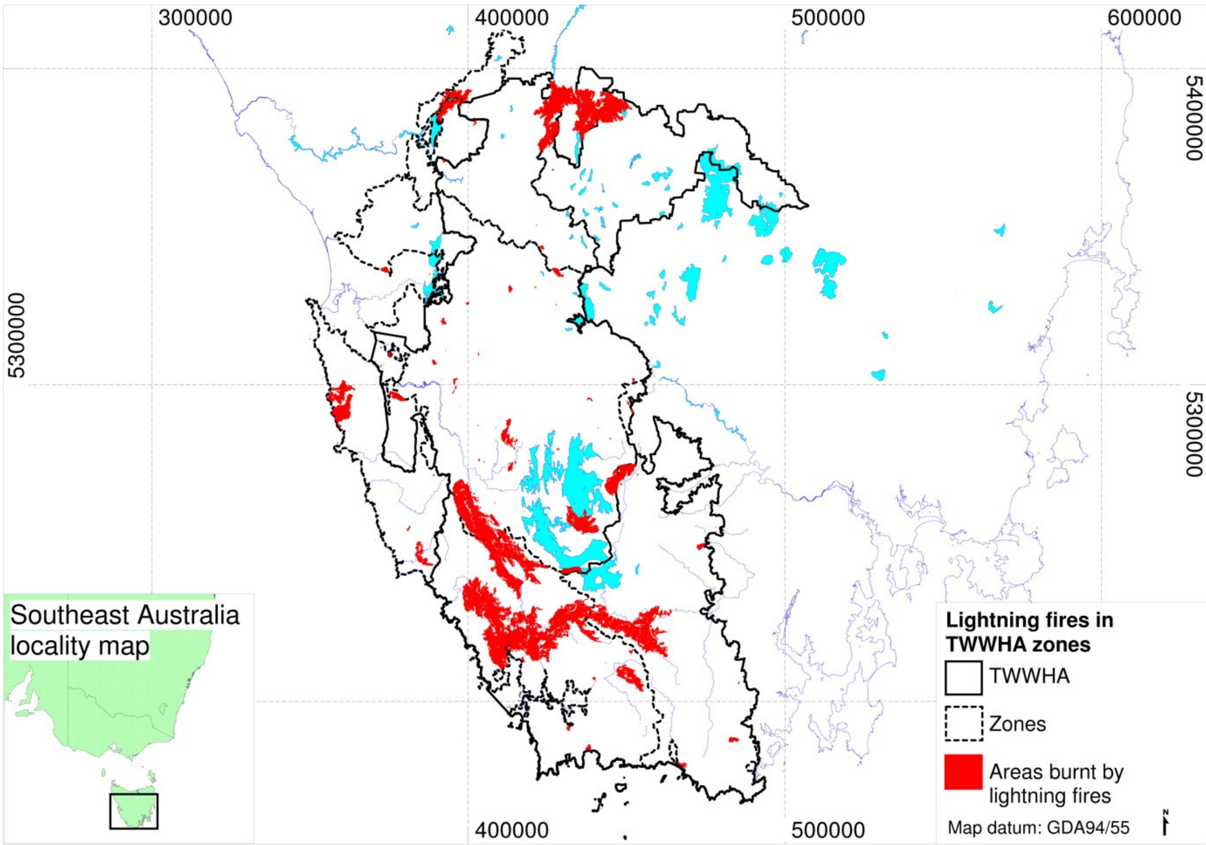
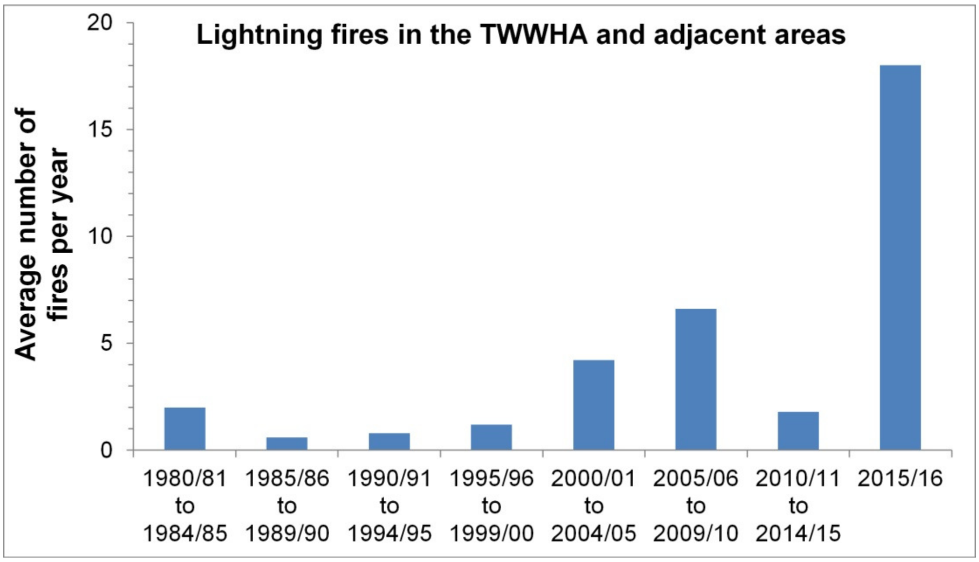
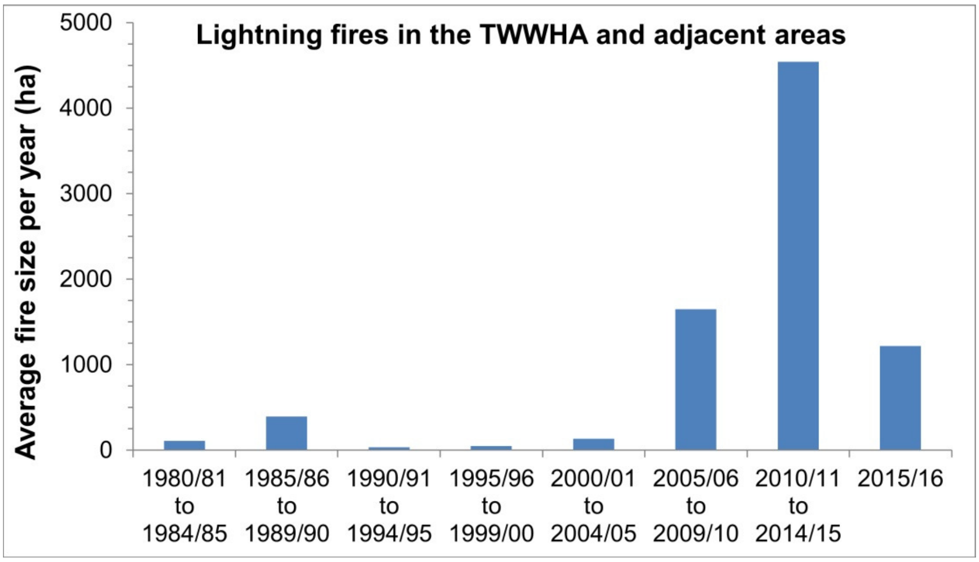


Figure 5. Areas burnt in the TWWHA and adjacent areas between 1980/81 and 2015/16.

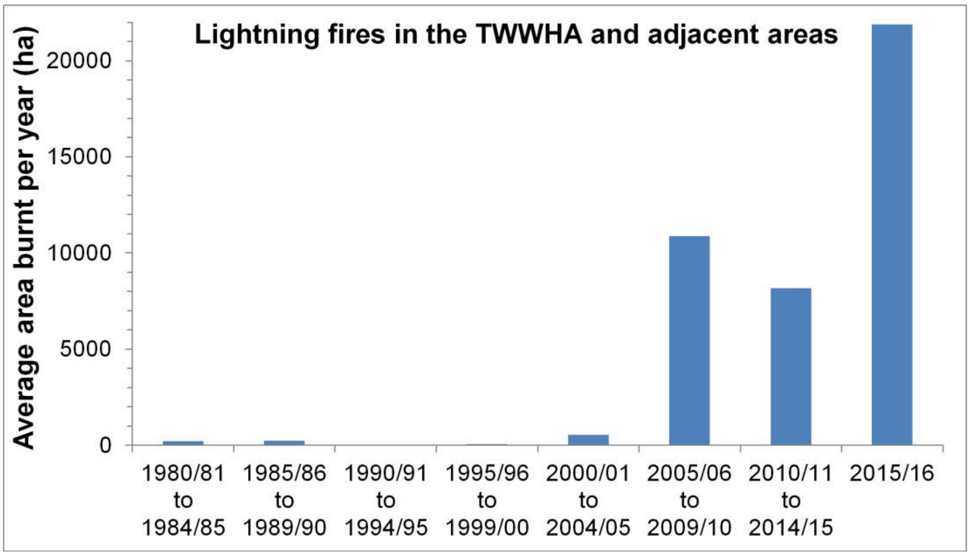
As examples, during the 2012/13 fire season, lightning ignited the Giblin River fire (Figure 7), which resulted in the biggest fire in southwest Tasmania since the 1933/34 fire season. During the 2015/16 fire season a large number of lightning caused fires occurred, especially in northwestern and western Tasmania. The lead up to the bushfire season had significantly below average rainfall, leading to the region having very dry soils and fuels by January 2016. On 13 January 2016, a major lightning storm passed through the region (Figure 8), resulting in nearly 2000 lightning strikes and starting over 70 fires in northwestern and western Tasmania, including at least 18 in the TWWHA and its adjacent areas. Between January and March 2016, these fires burned approximately 123 000 ha across Tasmania with about 20 100 ha (~1.27%) of the TWWHA being impacted.



a)



b)



c)

Figure 6. Lightning fire number, size and area burnt between 1980/81 and 2015/16.
Data sources: Marsden-Smedley 1998; Johnston and Marsden-Smedley 2001; PWS unpublished fire history database.

Figure 7. Lightning storm near Low Rocky Point on the evening of 03 January 2013.
Note: the Giblin River fire was started on 03 January 2013 by this group of storms.

Figure 8. Lightning storm at Wreck Bay mid-afternoon on 13 January 2016.
Note: This storm resulted in about 2000 lightning strikes and at least 18 fires in the TWWHA and adjacent areas.

4.2 Vegetation burnt in lightning fires between 1980 and 2016

The lightning fires that occurred in the different zones in the TWWHA and adjacent areas between 1980/81 and 2015/16 (Sections 2.3 to 2.5 and 4.1) have been assessed for the areas of fire-attributes vegetation type that were burnt (Table 5).

Overall, nearly 60% of the areas that were burnt during this period by lightning fires consisted of buttongrass moorland, about 12% wet forest, 6% mixed forest and 6% rainforest.

The majority of the area of buttongrass moorland, wet forest, mixed forest and rainforest respectively were burnt during the 2012/13 Giblin River fire on 03 January 2013, the Craycroft River fire in 2005/06, the Craycrof River and Reynolds Creek fires in 2005/06 (Figure 9) and the Lake Mackintosh fire in 2009/10.

Figure 9. Burning mixed forest near the Davey River during the 2005/06 Reynolds Creek fire.

Along with increases in the area burnt by lightning fires over the period between 1980 and 2016, there has been a marked increase in the economic and resource costs of controlling lightning fires in the TWWHA and adjacent areas (reflected in the increased personnel and equipment utilised by the PWS Fire Management Section over the past about 25 years).

Table 5. Areas of different fire-attributes vegetation types burnt by lightning fires in different zones and periods.

Vegetation type	1980/81 to 1984/85		1985/86 to 1989/90		1990/91 to 1994/95		1995/96 to 1999/00		2000/01 to 2004/05		2005/06 to 2009/10		2010/11 to 2014/15		2015/16		Total area	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
1:Cradle-StClair																		
Ac	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	9.4	0.2	9.9	0.1
Ag	3.8	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.2	0.0	0.0	389.7	8.0	400.3	4.4
As	15.1	11.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	0.2	0.0	0.0	118.2	2.4	140.4	1.6
Bs	0.0	0.0	0.0	0.0	7.1	6.6	37.5	64.0	1.1	100.0	331.3	8.6	0.0	0.0	152.2	3.1	529.3	5.9
Df	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.3	1.9	0.0	0.0	542.8	11.2	616.2	6.8
Dp	0.0	0.0	0.0	0.0	63.5	59.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	63.5	0.7
Ds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.3	14.3	0.2
Gr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0
Hh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.1	2.8	0.0
Mf	11.8	9.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	736.6	19.2	0.0	0.0	390.2	8.0	1138.6	12.7
Pt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.8	0.0
Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1110.0	28.9	0.0	0.0	91.7	1.9	1201.7	13.4
Rf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	458.9	12.0	0.0	0.0	265.8	5.5	724.7	8.1
Sp	1.4	1.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	12.7	0.3	14.1	0.2
Sr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wf,Wd	95.2	74.8	0.0	0.0	36.3	33.9	0.0	0.0	0.0	0.0	658.0	17.1	0.0	0.0	2646.9	54.4	3436.3	38.2
Wl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ws	0.0	0.0	0.0	0.0	0.0	0.0	21.1	35.9	0.0	0.0	455.2	11.9	0.0	0.0	196.5	4.0	672.8	7.5
Zz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	32.2	0.7	33.7	0.4
Total	127.2		0.0		107.0		58.7		1.1		3839.0		0.0		4866.4		8999.4	
	1.4		0.0		1.2		0.7		0.0		42.7		0.0		54.1			
2:Central Plateau																		
Ac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	61.7	0.6	61.7	0.6
Ag	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	27.2	0.0	0.0	0.0	0.0	2033.9	20.8	2039.9	20.8
As	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1958.5	20.0	1958.5	20.0
Bs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	0.1	14.7	0.1
Df	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.9	0.0	0.0	0.0	0.0	923.2	9.4	923.6	9.4
Dp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	0.1	14.7	0.1
Ds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0
Gr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	180.0	1.8	180.0	1.8
Pt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	0.1	7.6	0.1
Rf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	35.0	0.0	0.0	0.0	0.0	345.3	3.5	353.1	3.6
Sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	56.3	0.6	56.3	0.6
Sr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.1	0.2	18.1	0.2
Wf,Wd	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	35.9	0.0	0.0	0.0	100.0	4035.3	41.2	4043.2	41.2
Wl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ws	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.9	0.0
Zz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	132.0	1.3	132.0	1.3
Total	0.0		0.0		0.0		0.0		22.1		0.0		0.0		9782.5		9804.7	
	0.0		0.0		0.0		0.0		0.2		0.0		0.0		99.8			

Note: areas in hectares; between 1980/81 to 2014/15 burnt areas are 5year averages, 2015/16 areas were burnt in that fire season; vegetation types based on fire-attributes vegetation map derived from the TasVeg3 mapping program.

Table 5. Areas of different fire-attributes vegetation types burnt by lightning fires in different zones and periods, continued.

Vegetation type	1980/81 to 1984/85 Area	%	1985/86 to 1989/90 Area	%	1990/91 to 1994/95 Area	%	1995/96 to 1999/00 Area	%	2000/01 to 2004/05 Area	%	2005/06 to 2009/10 Area	%	2010/11 to 2014/15 Area	%	2015/16 Area	%	Total area Area	%
3:Gordon - Franklin																		
Ac	10.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	11.2	0.1
Ag	36.7	3.8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	43.3	0.3	0.0	0.0	13.7	0.3	93.8	0.4
As	57.0	5.9	0.0	0.0	0.0	0.0	0.0	0.0	22.3	1.4	25.2	0.2	0.0	0.0	53.8	1.2	158.2	0.7
Bs	299.1	31.1	64.4	44.4	0.0	0.0	10.8	39.3	245.2	15.1	8843.3	58.2	0.0	0.0	2511.8	58.1	11974.7	53.8
Df	9.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	0.8	569.6	3.7	0.0	0.0	13.6	0.3	605.9	2.7
Dp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	75.8	0.5	0.0	0.0	0.0	0.0	75.8	0.3
Gr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mf	28.1	2.9	64.8	44.6	0.0	0.0	0.0	0.0	552.4	34.1	1665.2	11.0	0.0	0.0	412.9	9.6	2723.4	12.2
Pt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rc	2.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	8.8	0.0
Rf	217.8	22.7	0.8	0.5	0.0	0.0	1.1	3.9	302.6	18.7	1621.1	10.7	0.0	100.0	68.2	1.6	2211.4	9.9
Sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wf,Wd	246.2	25.6	14.9	10.2	0.0	0.0	6.3	23.0	68.1	4.2	1098.3	7.2	0.0	0.0	386.0	8.9	1819.9	8.2
Wl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ws	53.2	5.5	0.4	0.3	0.0	0.0	9.3	33.8	411.0	25.4	1218.3	8.0	0.0	0.0	710.4	16.4	2402.6	10.8
Zz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	0.3	28.3	0.2	0.0	0.0	152.2	3.5	185.6	0.8
Total	960.8		145.2		0.0		27.5		1620.1		15194.4		0.0		4323.1		22271.1	
	4.3		0.7		0.0		0.1		7.3		68.2		0.0		19.4			
4:West - South Coasts																		
Ac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	0.0	0.6	0.0	0.0	0.0	9.6	0.0
Ag	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.4	0.3	24.3	0.1	0.0	0.0	86.8	0.1
As	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	132.4	0.7	221.2	0.6	0.0	0.0	353.7	0.6
Bs	0.0	0.0	641.2	91.7	15.4	91.6	153.6	72.3	327.4	73.7	13134.1	64.5	31203.7	78.7	1996.6	68.3	47472.1	73.8
Df	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.8	0.1	18.0	0.0	0.0	0.0	44.8	0.1
Dp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ds	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.3	0.0	0.0	0.8	0.0	103.9	0.3	2.0	0.1	107.4	0.2
Gr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.6	0.0	0.7	0.0
Hh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.4	0.7	21.4	0.0
Mf	0.0	0.0	5.0	0.7	0.0	0.2	0.0	0.0	12.2	2.7	1373.2	6.7	678.6	1.7	121.1	4.1	2190.2	3.4
Pt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2	2.5	70.3	0.3	26.0	0.1	0.0	0.0	107.5	0.2
Rf	0.0	0.0	0.6	0.1	1.4	8.2	0.5	0.2	23.6	5.3	1856.1	9.1	387.3	1.0	232.5	7.9	2502.0	3.9
Sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wf,Wd	0.0	0.0	39.8	5.7	0.0	0.0	13.4	6.3	28.4	6.4	1210.4	5.9	2102.5	5.3	89.0	3.0	3483.5	5.4
Wl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ws	0.0	0.0	12.8	1.8	0.0	0.0	44.2	20.8	37.7	8.5	2481.1	12.2	4842.0	12.2	452.5	15.5	7870.2	12.2
Zz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.9	4.7	0.0	22.0	0.1	9.3	0.3	39.9	0.1
Total	0.0		699.4		16.9		212.4		444.4		20361.3		39630.1		2925.0		64289.4	
	0.0		1.1		0.0		0.3		0.7		31.7		61.6		4.5			

Note: areas in hectares; between 1980/81 to 2014/15 burnt areas are 5year averages, 2015/16 areas were burnt in that fire season; vegetation types based on fire-attributes vegetation map derived from the TasVeg3 mapping program.

Table 5. Areas of different fire-attributes vegetation types burnt by lightning fires in different zones and periods, continued.

Vegetation type	1980/81 to 1984/85		1985/86 to 1989/90		1990/91 to 1994/95		1995/96 to 1999/00		2000/01 to 2004/05		2005/06 to 2009/10		2010/11 to 2014/15		2015/16		Total area	
	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%	Area	%
5:Southeast TWWHA																		
Ac	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Ag	0.0	0.0	4.9	1.5	0.0	0.0	0.0	0.0	0.0	0.0	16.6	0.1	0.0	0.0	0.0	0.0	21.6	0.1
As	0.0	0.0	6.9	2.1	0.0	0.0	0.0	0.0	9.7	1.5	35.1	0.2	0.0	0.0	0.0	0.0	51.6	0.3
Bs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	540.6	81.9	10212.8	70.0	573.1	52.0	0.0	0.0	11326.5	67.8
Df	0.0	0.0	2.6	0.8	0.0	0.0	0.0	0.0	3.6	0.5	597.0	4.1	0.0	0.0	0.0	0.0	603.2	3.6
Dp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.8	0.1	0.0	0.0	0.0	0.0	9.8	0.1
Gr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.0
Mf	0.0	0.0	53.1	16.0	0.0	0.0	0.0	0.0	0.1	0.0	402.3	2.8	1.6	0.1	0.0	0.0	457.1	2.7
Pt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rc	0.0	0.0	2.1	0.6	0.0	0.0	0.0	0.0	1.0	0.1	21.6	0.1	93.2	8.4	0.0	0.0	117.9	0.7
Rf	1.0	100.0	54.8	16.5	0.0	0.0	0.0	0.0	4.8	0.7	234.0	1.6	45.7	4.1	0.0	0.0	340.4	2.0
Sp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wf,Wd	0.0	0.0	205.2	61.6	0.0	0.0	0.0	0.0	53.8	8.2	1019.2	7.0	51.7	4.7	0.1	100.0	1329.9	8.0
Wl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ws	0.0	0.0	3.5	1.0	0.0	0.0	0.0	0.0	46.5	7.0	2047.1	14.0	337.9	30.6	0.0	0.0	2434.9	14.6
Zz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.8	0.0
Total	1.0		333.1		0.0		0.0		660.1		14597.1		1103.1		0.1		16694.4	
	0.0		2.0		0.0		0.0		4.0		87.4		6.6		0.0			
Entire TWWHA and adjacent areas																		
Ac	10.7	1.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	9.4	0.0	0.6	0.0	71.6	0.3	92.5	0.1
Ag	40.5	3.7	4.9	0.4	0.0	0.0	0.0	0.0	6.1	0.2	129.1	0.2	24.3	0.1	2437.3	11.1	2642.2	2.2
As	72.0	6.6	6.9	0.6	0.0	0.0	0.0	0.0	32.0	1.2	199.7	0.4	221.2	0.5	2130.4	9.7	2662.3	2.2
Bs	299.1	27.5	705.7	59.9	22.5	18.2	202.0	67.7	1114.4	40.6	32521.5	60.2	31776.8	78.0	4675.2	21.4	71317.2	58.4
Df	9.4	0.9	2.6	0.2	0.0	0.0	0.0	0.0	17.3	0.6	1266.8	2.3	18.0	0.0	1479.6	6.8	2793.6	2.3
Dp	0.0	0.0	0.0	0.0	63.5	51.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.7	0.1	78.1	0.1
Ds	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	86.4	0.2	103.9	0.3	16.7	0.1	207.6	0.2
Gr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.9	0.0	0.9	0.0
Hh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	24.3	0.1	24.9	0.0
Mf	40.0	3.7	123.0	10.4	0.0	0.0	0.0	0.0	564.7	20.6	4177.2	7.7	680.2	1.7	1104.3	5.0	6689.3	5.5
Pt	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.8	0.0
Rc	2.6	0.2	2.1	0.2	0.0	0.0	0.0	0.0	12.2	0.4	1208.1	2.2	119.1	0.3	99.3	0.5	1443.3	1.2
Rf	218.8	20.1	56.2	4.8	1.4	1.1	1.6	0.5	338.7	12.3	4170.1	7.7	433.0	1.1	911.8	4.2	6131.5	5.0
Sp	1.4	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.0	0.3	70.5	0.1
Sr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.1	0.1	18.1	0.0
Wf,Wd	341.4	31.3	259.8	22.1	36.3	29.3	19.7	6.6	158.2	5.8	3985.9	7.4	2154.2	5.3	7157.3	32.7	14112.8	11.6
Wl	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ws	53.2	4.9	16.6	1.4	0.0	0.0	74.5	25.0	495.1	18.0	6201.7	11.5	5179.9	12.7	1360.3	6.2	13381.5	11.0
Zz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9	0.3	35.3	0.1	22.0	0.1	325.7	1.5	391.8	0.3
Total	1089.1		1177.7		123.9		298.5		2747.8		53991.7		40733.2		21897.2		122059.0	
	0.9		1.0		0.1		0.2		2.3		44.2		33.4		17.9			

Note: areas in hectares; between 1980/81 to 2014/15 burnt areas are 5year averages, 2015/16 areas were burnt in that fire season; vegetation types based on fire-attributes vegetation map derived from the TasVeg3 mapping program.

4. Climate change in the TWWHA between 1980 and 2100

The Climate Futures for Tasmania (CFT) data for the period 1980 to 2000 versus 2080 to 2100 generated by the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) has been reviewed (Love et al. 2016a, 2016b).

The parameters examined in the CFT data were wind speed, temperature, relative humidity (RH), Moorland Fuel Moisture (Mf), Moorland Fire Danger Rating (MFDR), Forest Fire Danger Rating (FFDR), Soil Dryness Rating (SDI), Dry Periods (DP), SDI Thresholds (SDI T) and Lightning Potential (LP).

This data indicates that, over the period 1980 to 2000 versus 2080 to 2100, there are only minor changes in wind speed (with the biggest increase in wind speed being restricted to September; Figure 10), MFDR (Figure 11) and RH (Figure 12).

Over this time period, there were moderate increases in the level of FFDR (Figure 13) and temperature (Figure 14), with minor decreases in the level of Mf (Figure 15).

In contrast, there were major increases in the levels of SDI (Figure 16; Table 6), Dry Periods (Figure 17a; Table 7) and SDI Thresholds (Figure 17b; Table 8), particularly in summer and autumn. The correlation between these three parameters was not unexpected due to their all being measures of rainfall.

The LP is expected to initially increase, and then decrease (Figure 18, Table 9).

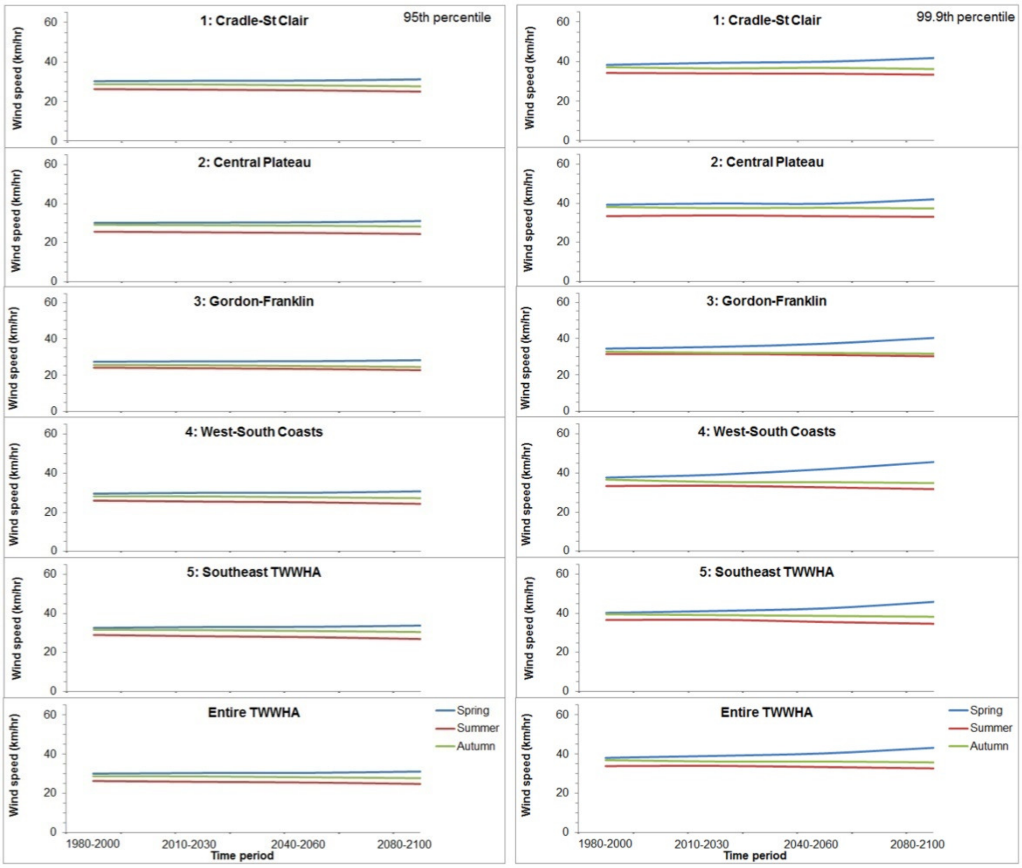


Figure 10. Wind speed between 1980 to 2000 and 2080 to 2100.

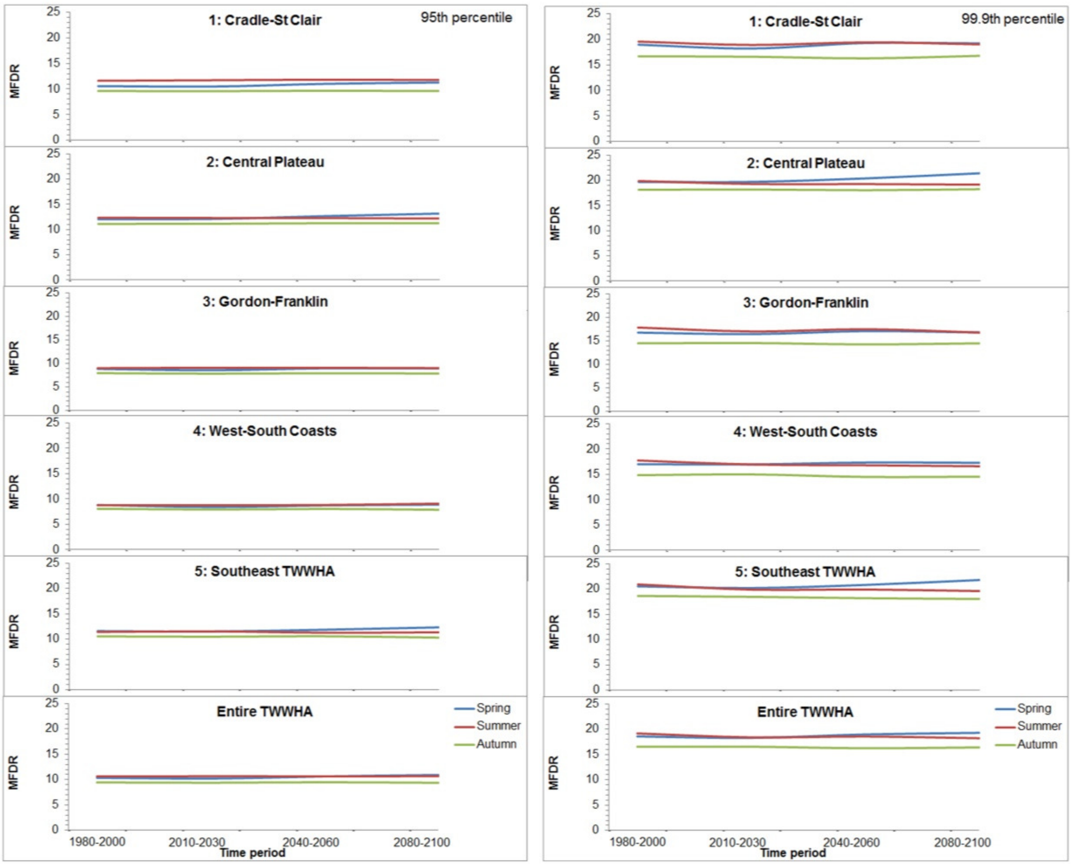


Figure 11. MFDR between 1980 to 2000 and 2080 to 2100.

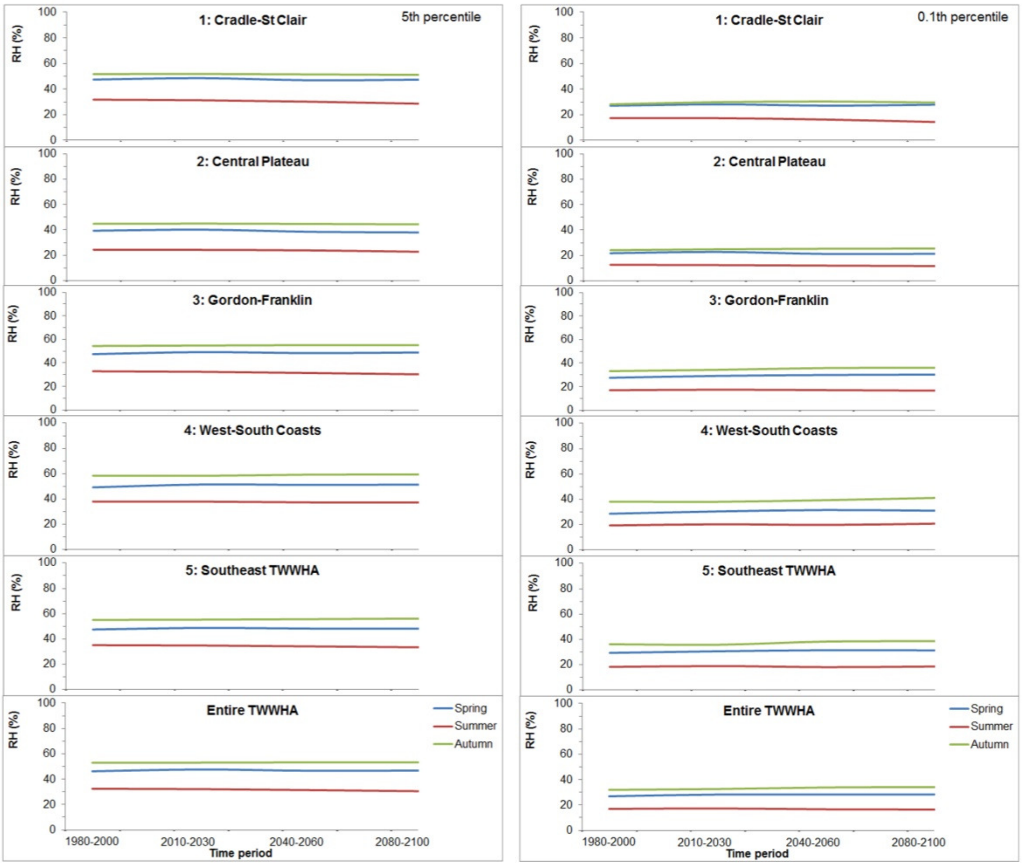


Figure 12. RH between 1980 to 2000 and 2080 to 2100.

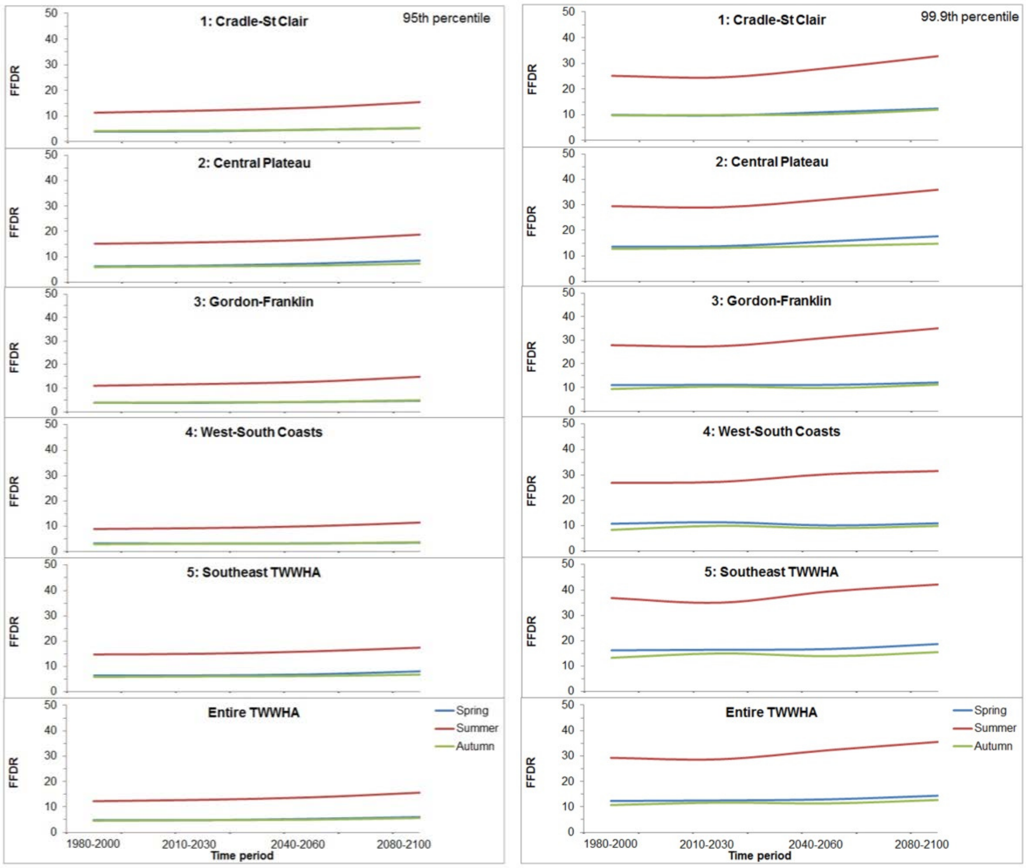


Figure 13. FFDR between 1980 to 2000 and 2080 to 2100.

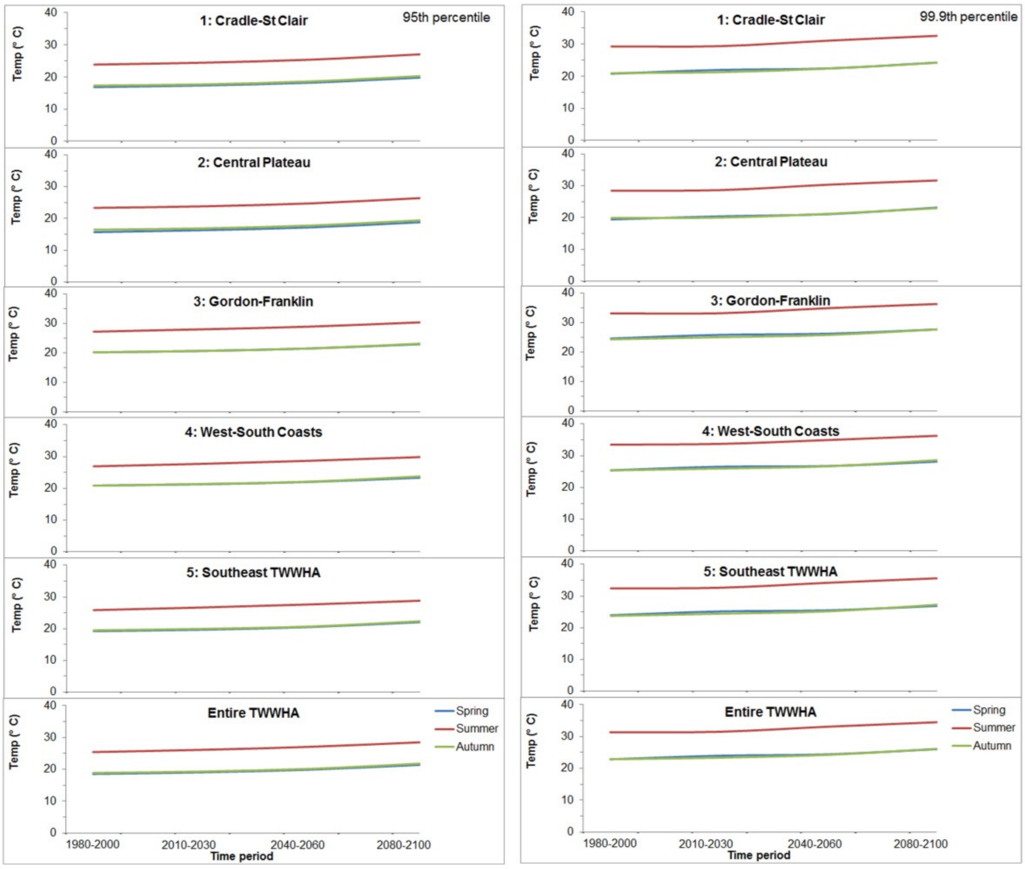


Figure 14. Temperature between 1980 to 2000 and 2080 to 2100.

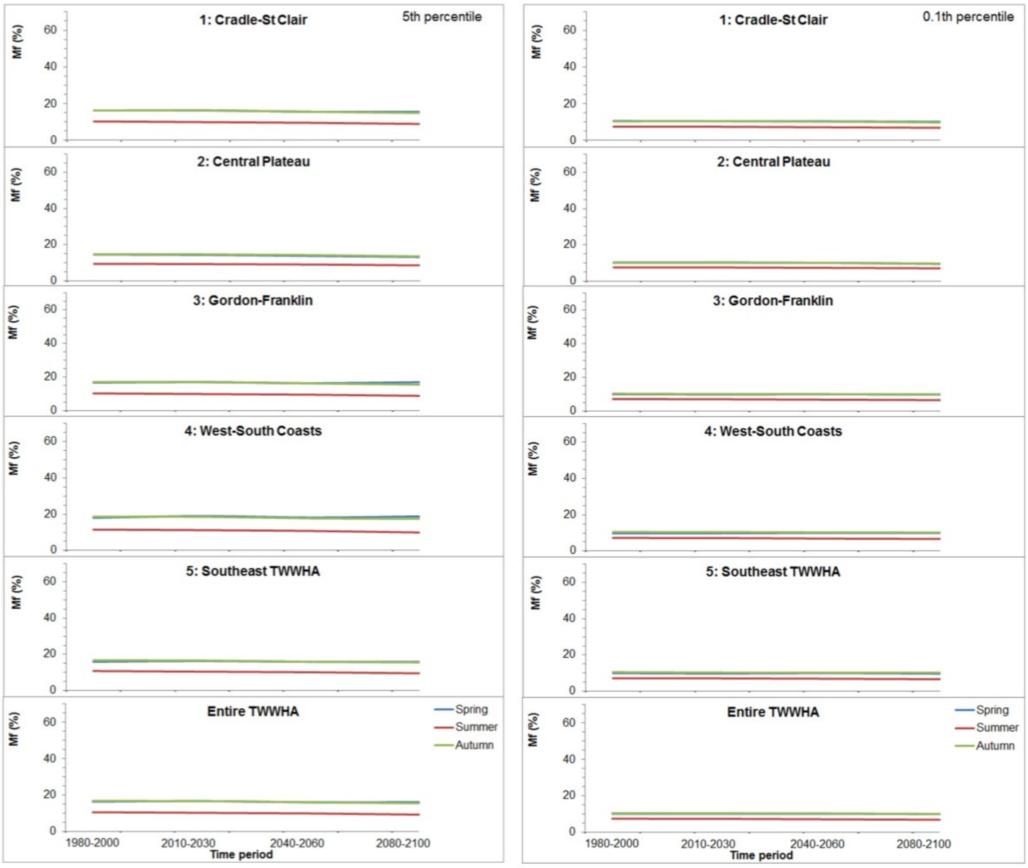


Figure 15. Mf between 1980 to 2000 and 2080 to 2100.

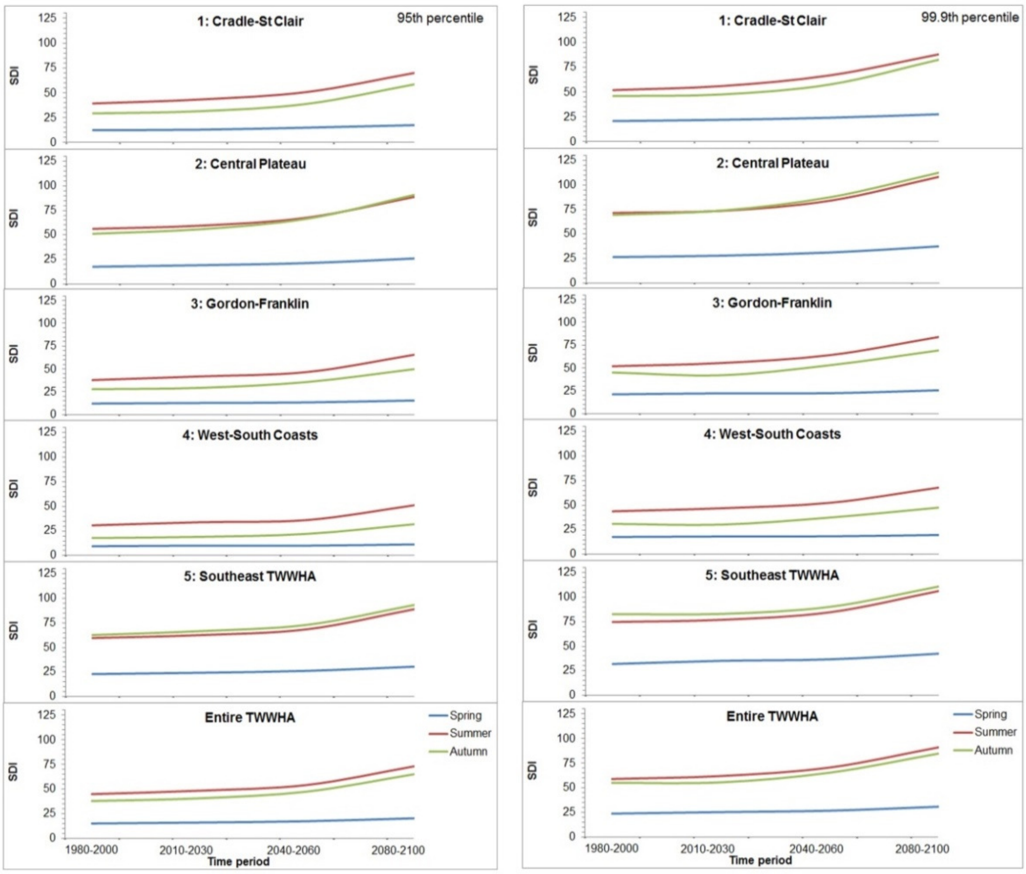
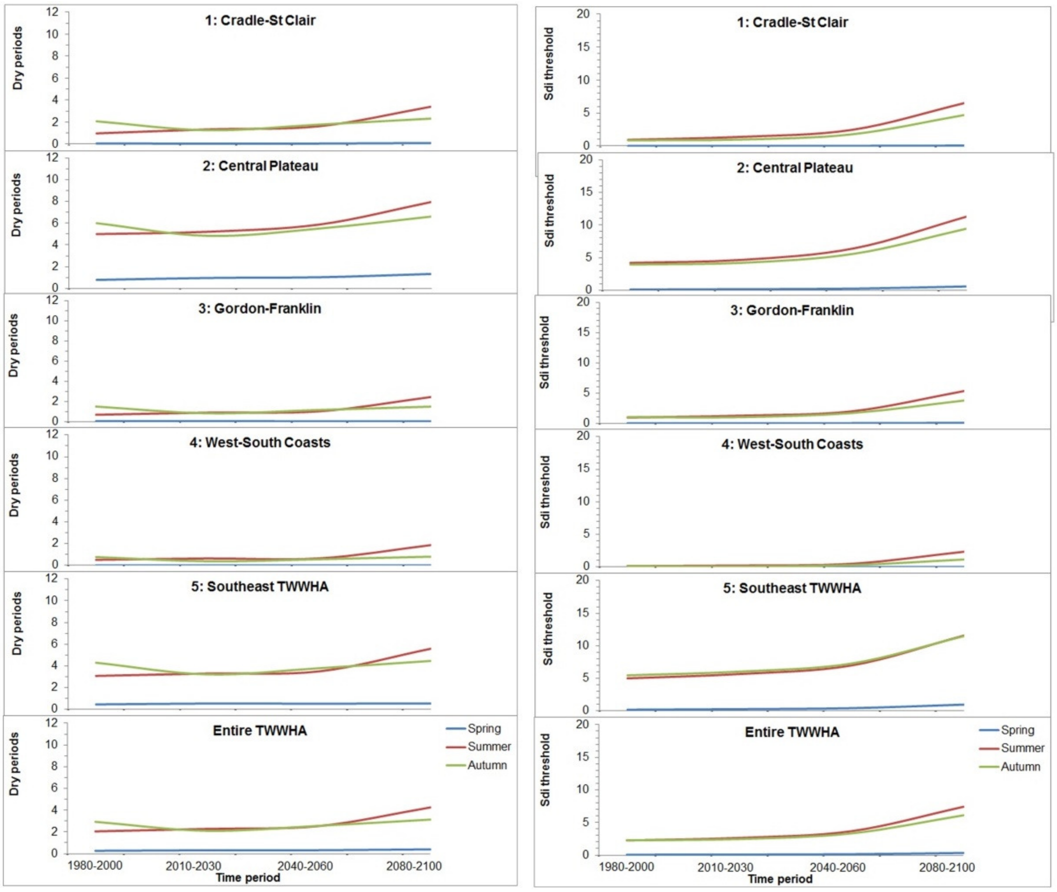


Figure 16. SDI between 1980 to 2000 and 2080 to 2100.

Table 6. Change in SDI in different time periods, zones and percentiles.

	1980 to 2000		2010 to 2030		2040 to 2060		2080 to 2100	
	SDI	%	SDI	%	SDI	%	SDI	%
				95th percentile				
1: Cradle - St Clair								
Spring	12.4	-	12.9	4.3	15.0	20.4	17.5	40.7
Summer	39.3	-	43.3	10.2	50.9	29.5	70.0	78.1
Autumn	29.3	-	31.5	7.8	38.9	33.1	58.5	99.9
2: Central Plateau								
Spring	17.4	-	19.0	9.1	21.3	21.8	25.9	48.7
Summer	56.2	-	59.4	5.8	67.7	20.4	89.0	58.3
Autumn	51.2	-	55.8	9.1	66.6	30.2	91.0	77.9
3: Gordon - Franklin								
Spring	12.1	-	12.7	5.2	13.4	10.3	15.5	27.7
Summer	37.8	-	41.8	10.6	46.6	23.3	65.6	73.5
Autumn	27.8	-	29.3	5.2	35.7	28.3	49.8	79.1
4: West - South Coasts								
Spring	9.6	-	10.2	6.2	10.1	5.8	11.4	19.5
Summer	30.7	-	33.9	10.4	36.2	17.7	51.3	66.7
Autumn	17.9	-	19.1	6.6	22.1	23.6	32.0	78.6
5: Southeast TWWHA								
Spring	22.9	-	24.2	5.8	26.2	14.3	30.4	32.9
Summer	59.7	-	62.6	4.9	68.6	14.9	89.1	49.2
Autumn	62.7	-	66.6	6.3	73.1	16.5	93.4	48.9
Entire TWWHA								
Spring	14.9	-	15.8	6.3	17.2	15.3	20.2	35.3
Summer	44.7	-	48.2	7.8	54.0	20.7	73.0	63.1
Autumn	37.8	-	40.5	7.1	47.3	25.2	64.9	71.9
				99.9th percentile				
1: Cradle - St Clair								
Spring	20.8	-	22.0	6.1	24.1	16.3	27.6	33.0
Summer	51.9	-	56.0	7.9	66.8	28.8	87.9	69.5
Autumn	45.9	-	47.6	3.6	57.6	25.5	82.5	79.7
2: Central Plateau								
Spring	26.4	-	27.9	5.5	31.1	17.8	37.4	41.7
Summer	71.6	-	73.7	3.0	84.2	17.6	108.5	51.6
Autumn	69.5	-	74.0	6.5	87.7	26.2	112.7	62.2
3: Gordon - Franklin								
Spring	21.0	-	22.2	5.3	22.3	6.0	25.5	21.2
Summer	51.9	-	55.4	6.8	64.1	23.5	83.9	61.8
Autumn	45.0	-	42.0	-6.7	53.0	17.8	69.2	53.8
4: West - South Coasts								
Spring	17.8	-	18.3	2.8	18.5	3.9	19.9	11.5
Summer	43.9	-	47.0	7.1	52.6	19.8	68.0	54.9
Autumn	31.2	-	30.4	-2.5	37.6	20.6	47.7	53.0
5: Southeast TWWHA								
Spring	31.9	-	35.1	10.1	36.7	14.9	42.5	33.2
Summer	74.7	-	77.0	3.0	84.8	13.4	106.4	42.4
Autumn	82.8	-	83.0	0.2	90.2	9.0	111.0	34.1
Entire TWWHA								
Spring	23.6	-	25.1	6.4	26.5	12.6	30.6	29.6
Summer	58.8	-	61.8	5.1	70.5	19.9	91.0	54.7
Autumn	54.9	-	55.4	0.9	65.2	18.9	84.6	54.2

Note: % is the percentage change relative to 1980 to 2000.



a) Dry Periods: days per month <50mm of rain; b) SDI Thresholds: days per month >50.

Figure 17. Dry Periods and SDI Thresholds between 1980 to 2000 and 2080 to 2100.

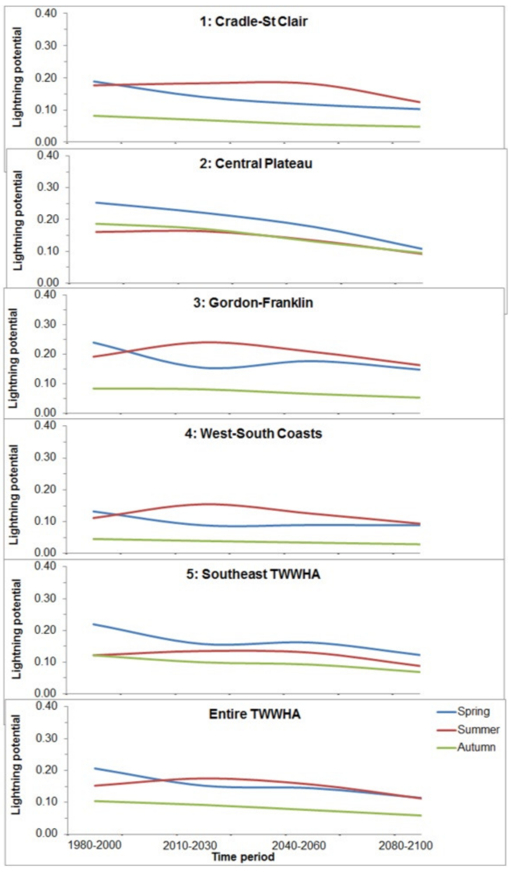


Figure 18. Lightning Potential between 1980 to 2000 and 2080 to 2100.

Table 7. Change in Dry Periods (DP) in different periods and zones.

	1980 to 2000		2010 to 2030		2040 to 2060		2080 to 2100	
	DP	%	DP	%	DP	%	DP	%
1: Cradle-St Clair								
Spring	0.1	-	0.0	-20.5	0.0	-12.6	0.1	84.3
Summer	1.0	-	1.3	37.7	1.6	67.7	3.4	250.0
Autumn	2.1	-	1.3	-39.3	1.8	-14.2	2.3	11.8
2: Central Plateau								
Spring	0.8	-	0.9	23.1	1.0	32.1	1.3	71.5
Summer	5.0	-	5.2	4.3	5.9	17.8	8.0	59.3
Autumn	6.0	-	4.8	-19.5	5.5	-8.2	6.6	10.2
3: Gordon - Franklin								
Spring	0.0	-	0.0	13.1	0.0	-45.6	0.0	-20.4
Summer	0.7	-	0.9	31.4	1.0	50.5	2.4	260.2
Autumn	1.5	-	0.8	-45.0	1.2	-22.6	1.5	-0.5
4: West - South Coasts								
Spring	0.0	-	0.0	69.2	0.0	-90.7	0.0	-79.4
Summer	0.5	-	0.6	24.8	0.6	25.7	1.9	263.3
Autumn	0.8	-	0.4	-50.2	0.6	-26.4	0.8	4.1
5: Southeast TWWHA								
Spring	0.4	-	0.5	17.8	0.5	14.6	0.5	19.9
Summer	3.1	-	3.3	7.3	3.5	13.9	5.6	81.9
Autumn	4.3	-	3.2	-25.1	3.8	-11.8	4.5	4.0
Entire TWWHA								
Spring	0.3	-	0.3	19.5	0.3	21.4	0.4	50.9
Summer	2.0	-	2.3	11.2	2.5	23.9	4.3	107.7
Autumn	2.9	-	2.1	-28.2	2.6	-12.5	3.1	7.2

Note: % is the percentage change relative to 1980 to 2000.

Table 8. Change in SDI Thresholds (SDI T) in different periods and zones.

	1980 to 2000		2010 to 2030		2040 to 2060		2080 to 2100	
	SDI T	%	SDI T	%	SDI T	%	SDI T	%
1: Cradle-St Clair								
Spring	0.0	-	0.0	1500	0.0	8400	0.1	32700
Summer	0.9	-	1.4	46.4	2.4	159.9	6.5	590.7
Autumn	0.9	-	1.0	13.4	1.8	106.7	4.7	447.4
2: Central Plateau								
Spring	0.1	-	0.1	78.0	0.2	196.4	0.6	647.0
Summer	4.2	-	4.6	11.1	6.4	53.8	11.3	170.3
Autumn	3.9	-	4.2	7.1	5.6	42.9	9.5	141.3
3: Gordon - Franklin								
Spring	0.0	-	0.0	12.5	0.0	76.8	0.1	365.6
Summer	1.0	-	1.3	31.7	2.0	107.3	5.3	457.6
Autumn	1.0	-	1.0	-0.8	1.7	66.9	3.8	269.4
4: West - South Coasts								
Spring	0.0	-	0.0	-66.7	0.0	-100.0	0.0	466.7
Summer	0.2	-	0.2	42.7	0.5	206.9	2.4	1321.4
Autumn	0.1	-	0.1	-40.5	0.3	103.5	1.2	679.5
5: Southeast TWWHA								
Spring	0.2	-	0.2	48.0	0.4	139.5	0.9	466.5
Summer	5.0	-	5.7	13.3	7.0	40.0	11.6	131.9
Autumn	5.4	-	6.0	10.5	7.3	33.5	11.5	110.8
Entire TWWHA								
Spring	0.1	-	0.1	55.5	0.1	157.7	0.3	534.7
Summer	2.2	-	2.6	17.2	3.7	63.4	7.4	229.9
Autumn	2.3	-	2.5	7.9	3.3	46.1	6.1	168.2

Note: % is the percentage change relative to 1980 to 2000.

Table 9. Change in Lightning Potential (LP) in different periods and zones.

	1980 to 2000		2010 to 2030		2040 to 2060		2080 to 2100	
	LP	%	LP	%	LP	%	LP	%
1: Cradle-St Clair								
Spring	0.19	-	0.14	-25.5	0.12	-37.9	0.10	-45.5
Summer	0.18	-	0.18	3.6	0.18	2.8	0.12	-29.5
Autumn	0.08	-	0.07	-16.1	0.06	-32.7	0.05	-41.3
2: Central Plateau								
Spring	0.25	-	0.22	-12.8	0.18	-30.1	0.11	-57.6
Summer	0.16	-	0.16	1.3	0.13	-16.6	0.09	-43.1
Autumn	0.19	-	0.17	-8.8	0.13	-29.8	0.09	-49.5
3: Gordon - Franklin								
Spring	0.24	-	0.15	-35.7	0.18	-26.3	0.15	-38.4
Summer	0.19	-	0.24	25.3	0.21	8.9	0.16	-15.1
Autumn	0.08	-	0.08	-3.2	0.06	-22.0	0.05	-37.1
4: West - South Coasts								
Spring	0.13	-	0.09	-32.9	0.09	-32.3	0.09	-32.8
Summer	0.11	-	0.15	38.5	0.13	12.4	0.09	-15.9
Autumn	0.05	-	0.04	-13.5	0.03	-25.3	0.03	-36.6
5: Southeast TWWHA								
Spring	0.22	-	0.16	-28.3	0.16	-26.3	0.12	-44.1
Summer	0.12	-	0.13	11.1	0.13	6.8	0.09	-27.6
Autumn	0.12	-	0.10	-18.0	0.09	-23.9	0.07	-43.2
Entire TWWHA								
Spring	0.21	-	0.15	-26.3	0.14	-30.1	0.11	-44.9
Summer	0.15	-	0.18	14.9	0.16	2.3	0.11	-26.5
Autumn	0.10	-	0.09	-11.6	0.08	-27.3	0.06	-43.6

Note: % is the percentage change relative to 1980 to 2000.

5. Discussion

Fire has been a component of the area now covered by the TWWHA for thousands of years resulting in the development of a complex mosaic of fire-dependent and fire-sensitive flora, fauna and soils. Assessment of the information on lightning fires and climate change indicates that it is not operationally practical, ecologically desirable nor economically possible to exclude fire from this region.

This means that in order to manage and maintain the region's world heritage values, it will be necessary to perform fire management operations in the region's fire-dependent vegetation such as buttongrass moorlands and native grasslands, along with fire exclusion in fire-sensitive vegetation such as alpine coniferous heaths, coniferous rainforests and rainforests.

5.1 Flammability of vegetation and soils

The data examined in this report indicates that the major impacts that are expected to occur from climate change in the TWWHA and its adjacent areas are related to changes in vegetation and soil flammability. These changes will result from significant increases ($P<0.001$) in the SDI, Dry Periods and SDI Thresholds. This means that, when fires occur, the likelihood that areas of wet scrub, wet forest, mixed forest and/or rainforest will be dry enough to burn will be greatly increased, with corresponding increases in the potential for peat fires (Table 3). These peat fires will in turn have the potential to act as ignition sources for subsequent fires, resulting in further increases to the level of fire risk along with major increases in the costs and resources required to perform wildfire suppression. These increases in soil dryness are likely to be already occurring (ie within the 1980 to 2030 time period; Figures 16 and 17; Tables 6 to 8).

The climate change scenarios indicate that significant increases in LP in the Gordon - Franklin and West - South Coasts zones in the current time period (ie 2010 to 2030), followed by LP decreasing in subsequent periods (Figure 18; Table 9). This increase in LP in the current time period is probably being reflected in the very large increase in lightning fires since 2010 in these two zones (Tables 5 and 9).

By the 2080 to 2100 time period, it is possible that increases in vegetation flammability resulting from increases in the SDI, Dry Periods and SDI Thresholds may be offset to some extent by reductions in LP (Figure 18; Table 9). However, whether these decreases in fire ignitions actually occur and if so by how much, is highly uncertain if the increased vegetation and soil dryness results in increased peat fires. This means that the level of fire risk may not actually decrease.

Peat fires have the potential to result in long term and very high level adverse impacts to world heritage values (Figure 19). The TWWHA's organosols have been identified as a critical world heritage value (DPIPWE 2014) and there is a critical research need to identify the types and locations of oganosols that are at risk from climate change (note that it is possible that there are some areas of organosol that are at risk under the current climate, independent of future climate change).

At the current time in Tasmania, the relationships between organosol type and their potential to burn in wildfires are very poorly understood. These issues have been researched in detail in North America, where the critical factors were found to be related to the peat's organic and moisture contents, with the soil moisture content at which the soil would support combustion increasing as the percentage organic content increased (Frandsen 1987, 1997).

Figure 19. Peat fire in wet scrub during the 1993 Harrisons Opening fire.

From an Australian context, probably the only study to examine the potential for different oganosols to support combustion was the preliminary study conducted by Marsden-Smedley (1993). This work examined the potential for a range of buttongrass moorland soils to support combustion, and in common with Frandsen (1987, 1997), this study found that the potential for the soil to support combustion was strongly related to the soil's organic and moisture contents.

This means that the organosols most at risk are probably those which have high levels of organic matter and are located in areas that were in the past, too wet to sustain burning. However, under the increased dryness resulting from climate change, these organosols may have the potential to sustain burning.

As an example of the organosols potentially at risk, research conducted by di Folco (2007) indicated that in buttongrass moorlands, organosols with high organic and moisture contents are most likely to be located in gullies and flat areas and less likely to be located on ridges and slopes. Di Folco (2007) also found that the majority of buttongrass moorland organosols on ridges and slopes had relatively low organic contents, resulting in their having a low potential to sustain burning.

Note that this opinion as to the buttongrass moorland organosols which are most at risk from climate change is different to that published by Sharples (2011), who considered that the organosols most at risk from climate change were located on ridges and slopes.

It also needs to be noted that, independent of climate change, some organosols, especially on ridges and slopes, may be at risk post-fire from increased erosion by wind and/or water, oxidation resulting from being dried out, exposure following removal of above ground vegetation and/or the dissolving of carbon stocks by water.

5.2 Implications of climate change on operational fire management

Within the TWWHA and adjacent areas, the region's land manager, the PWS, conducts extensive buttongrass moorland planned burning in both spring and autumn. This burning is conducted when the region's soil and meteorological conditions are suitable (ie moist to wet soils, low wind speeds and relatively low temperatures and relatively high humidities).

The main aims of this planned burning are to reduce wildfire risk and maintain fire-dependent communities (see Marsden-Smedley et al. 1999; Marsden-Smedley 2009). As an example, during the 2013 Giblin River fire, the use of this burning strategy was shown to be highly effective at restricting the area burnt and reducing the burnt area by at least 20 000 ha (Marsden-Smedley 2014; French et al. 2016).

Current guidelines and research (eg Marsden-Smedley et al. 1999; Marsden-Smedley 2009; DPIPWE 2015; Mallick et al. unpublished) are indicating that for operational and fire ecology reasons, that planned burning will be optimised by utilising a mixture of spring and autumn burning to develop a mosaic of variable sized patches throughout the area of buttongrass moorland.

Under the current climate, the conditions suitable for conducting safe and effective buttongrass moorland planned burning occur more frequently in autumn than in spring. During the spring and autumn burning seasons, this is mainly due to autumn having shorter days than nights, a higher probability of having a high pressure cell centred over Tasmania and lower average wind speeds (BoM unpublished climate statistics). In addition, the duration of the burning season in autumn and spring respectively is typically about four to ten weeks versus two to six weeks. This means that, under the current climate, it is generally possible to achieve more planned burning in autumn than in spring.

The increases in autumn of SDI, Dry Periods and SDI Thresholds will mean that buttongrass moorland planned burning in the TWWHA and adjacent areas is highly likely to be adversely impacted. These impacts will mainly result from the wet scrub which is normally adjacent to buttongrass moorlands being dry enough to burn throughout autumn (ie having a SDI in excess of 10 to 15; Tables 3 and 6).

This means that in the near future it is highly probable that in most years planned burning in the TWWHA and adjacent areas will be largely restricted to spring. This will greatly decrease the potential for conducting planned burning whilst increasing the risk of fire escapes into non-target vegetation types. In addition, conducting planned burning only in spring has the potential to adversely impact ecological values which rely on either autumn burning, or a mix of autumn and spring burning.

In addition to the impacts to planned burning operations, the increases in peat fires will also result in major increases in the costs and resources required for performing wildfire suppression. These increases in wildfire suppression costs have the potential to be substantial. Peat fires are typically very difficult, slow and expensive to control. The only effective methodology is to physically dig out burning areas and saturate with water. In remote areas (ie most of the TWWHA) this digging out will need to be performed by hand with water being applied by hose lays and/or helicopters.

5.3 Fire return-time for fire-sensitive vegetation

Over the past 45 years, lightning fires have gone from about 0.1% of fires and 0.01% of the area that was burnt, to about 28% of fires and 78% of the area that was burnt (Bowman and Jackson 1981; Table 5).

Whilst over the past 35 years some areas of fire-senstive alpine coniferous heath, coniferous rainforest and rainforest have been burnt in the TWWHA and adjacent areas (Table 5), these burnt areas are far smaller than have occurred in the past.

For example, over the about 100 years prior to 1980, fires burnt between about a third and half of the area of King-billy pine (Brown 1988; Marsden-Smedley unpublished data; Figure 20), nearly a tenth of Huon pine (Peterson 1990); at least a third of Pencil pine (Corbett 1996) and at least a quarter of Deciduous beech (Robertson and Duncan 1991; see also Marsden-Smedley 1998; Johnston and Marsden-Smedley 2001). In addition, very extensive areas of Huon pine were flooded during the construction of hydro-electric schemes.

These vegetation communities are highly fire-senstive. Coniferous alpine heath and coniferous rainforest takes at least 500 to 1 000 years to recover from being burnt, while rainforest takes at least 100 years. These figures indicate that prior to 1980, the rates that these vegetation types were being destroyed were non-sustainable.

Figure 20. Burnt King-billy pine on Moonlight Flats, Southern Ranges.
Note: fire occurred in 1933/34 (Marsden-Smedley 1998).

The post fire recovery times stated above indicate that the area of coniferous alpine heath and rainforest will be reduced if fires average more than about 0.1 to 0.2% of the vegetation’s area per year. In the case of rainforest, the area of rainforest will be reduced in fires average more than about 0.4 to 1% of the rainforest’s area per year. Note that these figures assume that the vegetation is not being adversely impacted by other factors such as flooding or land clearing.

During the period 1980/81 to 2015/16, fires averaged about 0.01% of coniferous alpine heath, about 0.05% of coniferous rainforest and about 0.6% of rainforest per year (Table 9). Whilst significant, these areas are less than the vegetation’s potential post fire recovery rates (and far lower than those that occurred during the preceding about 100 years).

5.4 Effect of fire age on lightning fire potential in buttongrass moorlands

The majority of the area burnt by lightning fires between 1980/81 and 2015/16 consisted of buttongrass moorland (Tables 2 and 5) with most of this area being burnt in the Gordon - Franklin and West - South Coasts zones. This result is not unexpected due to buttongrass moorland's very high flammability and these zones having extensive buttongrass moorland covered plains.

Further examination of the lightning fire (Section 2.5) and vegetation (Section 2.3) maps indicates that all of the recorded lightning fires between 1980/81 and 2015/16 started in long unburnt vegetation. This is despite about a third of the area of buttongrass moorland (along with significant areas of other vegetation types) in the TWWHA and its adjacent areas having a fire age of less than 35 years.

This indicates that it is highly probable that there is, at least in buttongrass moorland, an interaction between fire age and the potential for lightning to result in a sustaining fire. This interaction between fire age and the likelihood that lightning will result in a sustaining fire is probably due to smaller amounts of rain being required to extinguish fires in younger aged moorlands (which normally low density open fuel arrays) than is the situation in older moorlands (which normally have closed high density fuel arrays).

The models developed for predicting fuel moisture and whether fires will self-extinguish or sustain in buttongrass moorland can be used to estimate the amount of rainfall required for fuel moistures to exceed the level where fires will sustain (Marsden-Smedley and Catchpole 2001; Marsden-Smedley et al. 2001). These models predict that markedly smaller amounts of rain will result in non-sustaining fires in low density open moorlands than is the situation in closed high density moorlands (Table 10).

The data in Table 10 also indicates that planned burning in buttongrass moorlands, by resulting in more open fuel arrays, has the potential to significantly reduce the risk of lightning fires sustaining.

Table 10. Buttongrass moorland sustaining versus or self-extinguishing fires in low and medium productivity sites.

	Rain=0.05mm		Rain=0.2mm		Rain=0.5mm		Rain=1.0mm		Rain=1.5mm	
Wind	Low	Med	Low	Med	Low	Med	Low	Med	Low	Med
1	No-go	Go	No-go	No-go	No-go	No-go	No-go	No-go	No-go	No-go
2	No-go	Go	No-go	No-go	No-go	No-go	No-go	No-go	No-go	No-go
5	No-go	Go	No-go	Go	No-go	No-go	No-go	No-go	No-go	No-go
10	Go	Go	No-go	Go	No-go	Go	No-go	No-go	No-go	No-go
20	Go	Go	Go	Go	No-go	Go	No-go	Go	No-go	No-go
30	Go	Go	Go	Go	Go	Go	No-go	Go	No-go	Go
40	Go	Go	Go	Go	Go	Go	Go	Go	Go	Go

Note: data predicted using the models in Marsden-Smedley and Catchpole (2001), Marsden-Smedley et al. (2001); no-go = non-sustaining fire, go = sustaining fire.

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