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USING PRE- AND POST-FIRE LIDAR TO ASSESS THE SEVERITY OF THE 2019 TASMANIAN BUSHFIRES

Field survey methods

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Cover: Field work in process. Source: James Furlaud

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ABSTRACT

In January 2019, over 64,000 ha of bushland burned in the Riveaux Road fire in Tasmania's southern forests. Most of this burning occurred in tall wet eucalypt forest. These forests are considered to be highly flammable in dry conditions, but fires are infrequent due to the generally cool, wet climate in which they grow. As a result, limited data exists on the behaviour and effects of wildfire in these forests. Prior to these fires, extensive areas of these southern forests have been studied in-depth. In 2014, a large area of the forests that burned were mapped with aerial LiDAR, a remote-sensing technology that can characterise three-dimensional forest structure. Further, in 2016, detailed field-based measurements of fuel load, structure, and hazard were taken at 12 permanent plot which subsequently burned in 2019. Hence, the 2019 fires in Tasmania represent a globally-rare opportunity to characterise the severity of a large wildfire using pre-fire and post-fire data. In October 2019, the Department of Primary Industries, Parks, Water and Environment (DPIPWE) in Tasmania, along with five other BNHCRC end-users and the University of Tasmania, launched a project to do just this, using remote-sensing and field-based data to create a detailed case study of the 2019 Riveaux Rd. Fire, and to untangle the drivers of fire severity in tall wet eucalypt forests.

Here, we present the Methodology this study. We took measurements at the 12 permanent plots that burned, dividing our measurements based on 2 levels of detail, based on the level of detail of the pre-fire measurements. In four plots we took 'Level 1' measurements, undertaking an overstorey census over 1 ha, assessing overstorey mortality. In 12 plots, we took 'Level 2' measurements, which involved characterising understorey phiognomy, structure fuel load, and fire hazard along 3-4 transects at each plot. For Level 1&2 measurements we also took numerous fire severity measurements, such as char height and burnt tip diameter. We also developed a 'Level 3' methodology of mostly qualitative fire severity indices that could be quickly conducted at many sample points across the landscape. quantifying fuel load, structure, mortality, hazard, and fire severity indices such as char height and burnt tip diameter. We also outline the next steps to be taken for this project.

END-USER STATEMENT

Steve Leonard, *Natural Values Conservation Branch, Department of Primary Industries, Parks, Water and Environment, TAS*

Improved understanding of fire severity and ecosystem recovery is a fundamental for assessing fire impacts and planning post-fire environmental management and recovery works. The fact that the Riveaux Road fire occurred over an area for which we have a rich array of long-term ecological data presents a rare opportunity to comprehensively examine fire effects in eucalypt forest. This project will generate new insights into fire behaviour and effects on ecosystems and fuels, which will inform management agencies response to future fires.

INTRODUCTION

In order to validate airborne LiDAR and satellite-derived measurements assessing the severity of the 2019 Riveaux Road Fire in Southwest Tasmania, we conducted a field-based fire-severity assessment during a 3-month period from November 2019 – January 2020. We used three different methodologies to obtain field-based fire severity estimates at three different levels of detail. We refer to these three different methodologies as follows:

1. Level 1 methods focused on overstorey (>10cm DBH) tree mortality and species survival across the entirety of four 1ha Tasmanian Tall Forest Southern Ausplots sites that burned in the fire

2. Level 2 methods involved measuring 3-4 30m transects to assess post-fire fuel, fire hazard, and fire severity, focusing on the elevated, near-surface, and surface fuels. This was done across 12 chronosequence plots and the 4 Ausplots

3. Level 2 methods involve point severity assessments of fire impact across the wider fire landscape.

A map of the locations of the Level 1, 2 and 3 assessments is presented in Figure 1. As is described in the Methodology, each of these assessments involved different methodologies and data.

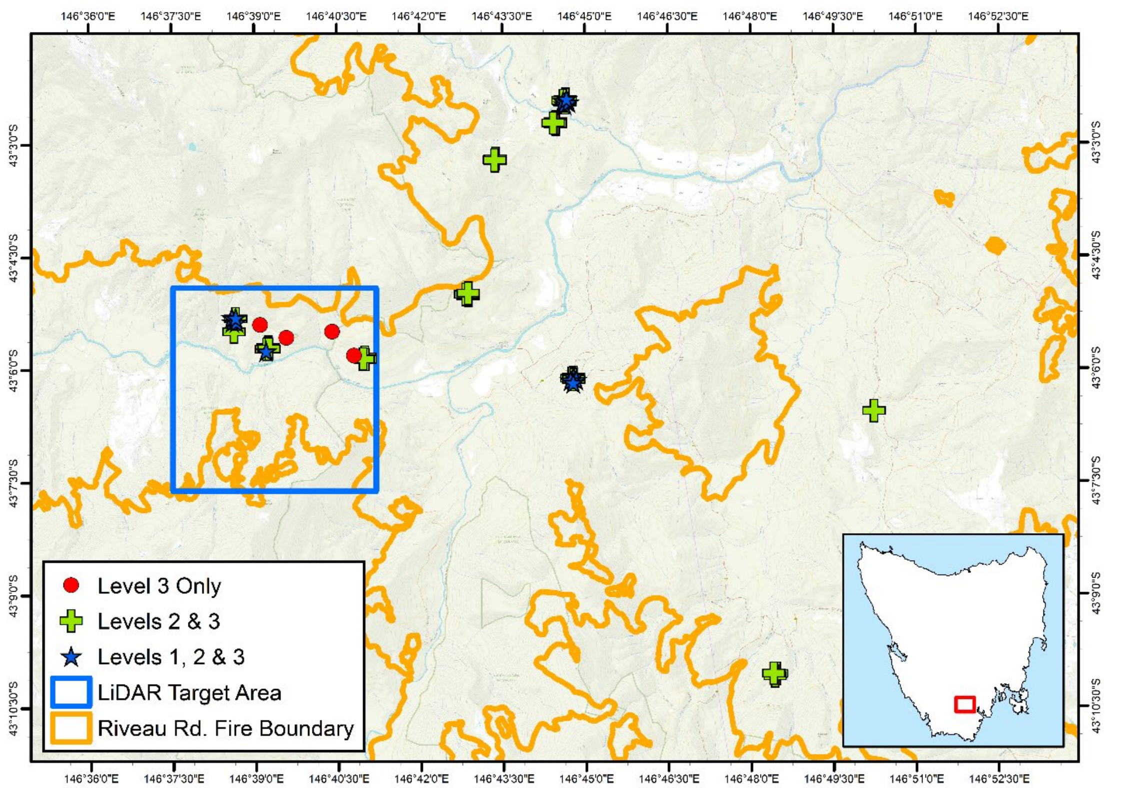

FIGURE 1 MAP OF LOCATIONS IN WHICH LEVEL 1, 2, AND 3 ASSESSMENTS WERE TAKEN.

METHODOLOGY

LEVEL 1

For our Level 1 methodology, we performed a high-resolution assessment of fire severity in the overstorey by measuring the mortality of all trees >10cm DBH in the four Ausplots Tall Forest sites. At these sites all woody stems >10cm DBH have been given an aluminium tag with a unique id number with their location recorded on a 100x100m grid, we defined these trees as the overstorey trees [1]. Tree maps have then been created with species, unique id, and location of each tree for all the Ausplots [2].

Using the aforementioned tree map at each site, the tagged trees were assessed for fire severity and tree mortality as follows:

1. Tree level mortality was assessed as dead or alive. This was assessed on the presence of any green leaves. This means a tree with no canopy leaves, but epicormic or basal resprouting was considered live. A tree with no canopy leaves or no resprouting was considered dead. If a tree was likely to have been dead before the fire, then this was also noted in the data.
2. Fire severity was assessed in 2 ways. First canopy scorching was assessed visually with a percentage given for canopy scorched. Scorching was considered as visible charring or browning of leaves or, given the 10-11-month time frame since the fire, defoliation of the leaves. An understorey tree with a few dead charred leaves remaining and the rest missing was recorded as 100% scorched. Where the fire severity is more difficult to ascertain then a note was made about whether the canopy has been scorched or just defoliated due to fire stress.

   Secondly, trees were also assessed for epicormic or basal resprouting with the occurrence of these recorded. These are considered stress responses to fire and therefore an indicator of the impact of the fire on an individual tree.
3. Finally, notes were also made if a tagged tree had fallen, and the cause of this, if it could be discerned, was noted. This is important as without such notes trees that have fallen post fire should not be included in the fire tree mortality count.

In keeping with the Ausplot methodology any previous untagged trees >10cm DBH were also assessed for fire severity and their status also recorded. The species, and DBH, of any new tree was recorded and noted and each occurrence given the identifier NEW. Trees were marked with spray paint once accessed to limit double counting and ease data collection.

LEVEL 2

The Level 2 methodology was developed to provide a detailed assessment of post-fire fuel loads, especially in the surface, near-surface, and elevated layers. All Level 2 assessment occurred at sites in which fuel loads were measured using the same methodology 3-5 years prior to the fire. Comparison of live and dead fuel loads before and after the fire will allow for a thorough assessment of fuel consumption and fire severity. We also measured standard fire-severity metrics in the elevated layer such as scorch height and burnt-tip diameter. All assessments and measurements were made using three or four 30m fuel transects at each plot.

Surface and near-surface fuels

We set up 1x1 m quadrats between the 7-8m and 21-22m marks along the transect tape. Along the inside edge of each quadrat we measured the litter depth and grass height at 10cm intervals between 7.0 and 7.8 m, and 21.2 and 22.0 m on the transect tape. We then collected all woody and vegetative plants <0.5m in height, live grasses, fine fuels (all detached dead material, including twigs <6mm in diameter), and coarse fuels (twigs between 0.6 and 2.5 cm diameter) from each quadrat. We dried these samples to a constant weight at 70°C, weighed them to obtain dry weights, and estimated the tonnes per hectare (t/ha) fuel load directly. Lastly, we measured the depth of the topmost organic layer in the soil.

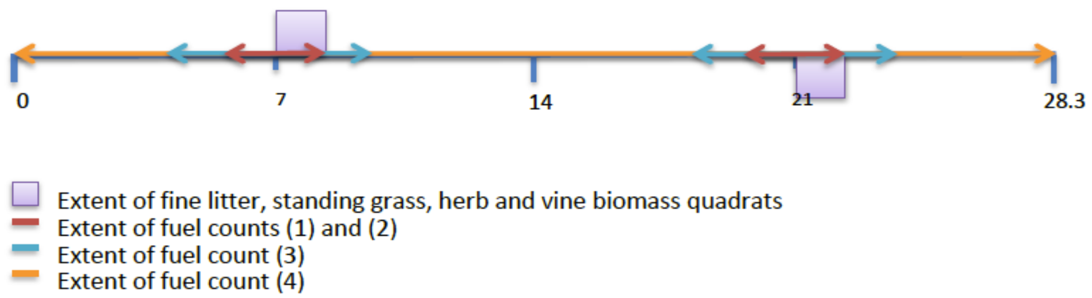

FIGURE 2 EXTENT OF WOODY FUEL COUNTS AND SURFACE FUEL QUADRATS

Downed woody fuels

We measured downed woody fuels along each transect to estimate the biomass of this fuel type. Downed woody fuels were defined as any detached (not rooted in the ground) woody material. We divided downed woody fuels into 2 categories, based on 10, and 100-hour moisture time-lag classes:

a) 2.5 – 7.6cm diameter

b) >7.6cm diameter

For category b, we measured the diameter of every log or fragment that intercepted the transect tape in this size class. The diameter was measured perpendicularly to the direction of the log at the point of intersection. For category a, we counted the number of woody intersects between the 5-7m and 19-23m marks on the transect tape. A full diagram of the locations of the quadrats and woody fuel counts along the transect tape is presented in Figure 2. We then used a standard technique for converting the diameter of downed logs into t/ha, assuming a relative density of 0.4.

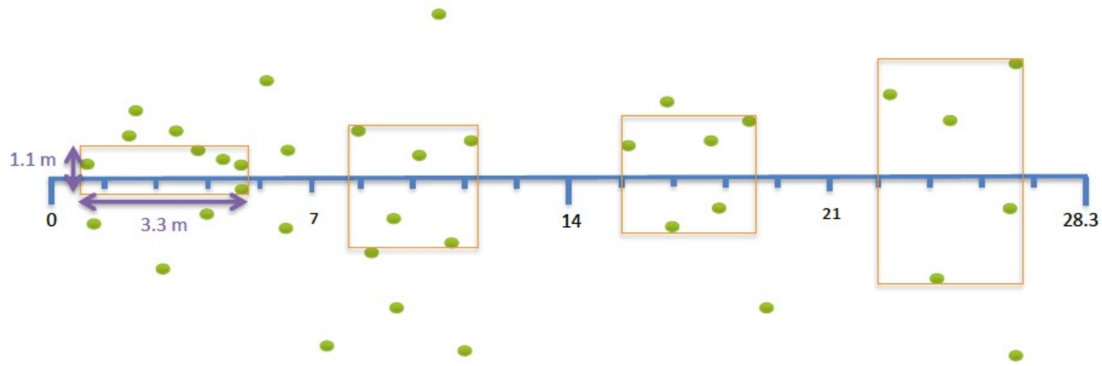

FIGURE 3 DIAGRAM OF CHOICE OF SHRUBS AND MEASUREMENT OF SURROUNDING RECTANGLE

Elevated fuels

To measure live and dead standing plants in the elevated fuel layer (hereafter referred to as "shrubs"), we split the transect tape into four 7m long subsections. In each of these subsections we measured the five live shrubs and the five standing dead shrubs that were perpendicularly closest to the tape (see Figure 3). We did not measure any shrubs more than 5m away from the transect tape. We considered any plant that was greater than 0.5 m in height and less than 10cm in DBH to be a shrub. We also considered all tree ferns as "shrubs". In each subsection, we measured the height, DBH (where applicable), and basal diameter of each shrub. We also estimated the canopy length and width of each shrub to measure canopy cover. For each tree fern we recorded the length of the stem. We also measured the length and width of a rectangle bounding the group of five shrubs so we could estimate density (Figure 3). These measurements gave us estimates of the density and height of the elevated fuels layer. Using the diameter and height measurements we will be able to accurately predict the biomass of each live and dead plants and obtain t/ha elevated fuel load estimates. Lastly, we measured shar height and burnt tip diameter on each live and dead plant for which this was applicable.

Further measurements

Lastly, we took a number of additional measurements. We measured char heights of overstorey (>10cm DBH) non-stringy bark trees adjacent to each transect. In the case of the Ausplots, measured all applicable trees within the subplot the transect bisected [1]. In the case of the chronosequence plots we measured all applicable trees within 3-7 m of the transect, varying this width with the goal of measuring 10-20 char heights per transect. Lastly, we performed qualitative hazard score assessments, using the mid-point of each transect as an assessment point, according to the methodology of Hines et al. [3], to compare these to pre-fire hazard scores.

LEVEL 3

The purpose of the Level 3 methodology was to perform quick ground truthings of fire severity to validate measurements derived from LiDAR and aerial photos. These methods were deigned to obtain numerous on ground post-fire severity data. As such it was designed to be a quick assessment taking around 10-15 minutes for each point.

Initially, level 3 surveys were performed on existing permanent plots in which the level 2 and/or level 1 methodologies were employed. This provided an assessment of the validity of these rapid assessment methods using the more detailed level 1 & 2 data. Four additional roadside points were sampled to further refine the methodology. All points were a minimum of 50m away from any road. Within similar vegetation and disturbance histories, all points were at least 500m away from one another.

At each point the following data was recorded:

1. **Plot location**
2. **Date**
3. **Vegetation type** – both overstorey and understorey species assemblage
4. **WLogging/Disturbance** – if the pre-fire disturbance history of site was known
5. **Crown scorching (%)** – percent of crown that was scorched by fire (assessed for the understorey and overstorey strata)
6. **Burnt surface (%)** – visual assessment of burnt grount litter and surface at a 5m radius centred on the point
7. **Rock cover (%)** – rock within a 5m radius of the point
8. **Slope (°)** – this was taken with a vertex hypsometer. If a vertex is unavailable this can also be achieved with a clinometer
9. **Aspect (°)** – taken with a compass facing the direction the slope is running. This can be taken at the same time as slope to ensure there is a point to reference to
10. **Status of the 5 nearest woody stems**

Methodology for selecting five nearest woody stems

Woody stems were selected by holding a pencil, at the pointy end, 30cm in front of nose in the manner of a basal sweep. The five closest trees/ larger than the end of the pencils were then assessed for their post-fire status according to following categories: dead, basal resprouting, epicormic and alive undamaged. The species name and percent canopy scorch for each woody stem was also noted. If trees were smaller than the end of a pencil the same process was used with the pencil held with the point in front of the eyes and this was used as the basal sweep.

Trees in which epicormic resprouting occurred were given a score on a scale from 0-5 based on the following criteria:

0. No epidemic resprouts
1. One or two epicormic sprouts (Figure 4a)
2. More than 3 epicormic reprouts along the trunk (Figure 4b)

3. Vigorous epicormic sprouting from base of tree to lower canopy branches (Figure 4c)
4. Epicormic sprouting along tree trunk and lower canopy branches
5. Crown totally consumed, epicormic sprouting along trunk and entirety of the canopy, including upper canopy

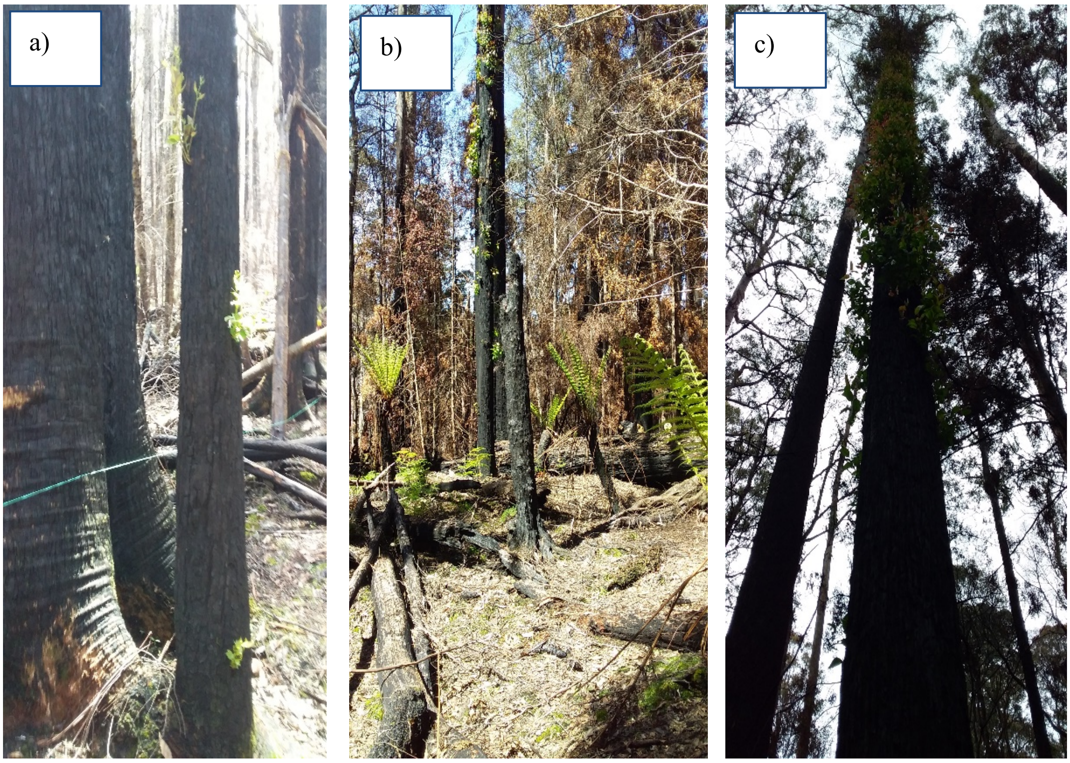

FIGURE 1 EPICORMIC RESPROUTING SCALE ASSESSMENT EXAMPLES WITH A) BEING A SCORE OF 1, B) A SCORE OF 2 AND C) A SCORE OF 3.

Level 3b sampling

We plan to add 20-40 more level 3 plots upon resumption of this project in the spring (in the immediate aftermath of the LiDAR flight). To select these points, we will use stratified sampling based on stand structure and fire severity so as to sample sites across different management histories and fire severity classes. We will measure points throughout the area targeted for the LiDAR flight using the constraints outlined above. Additionally, we will assess percent consumed by the fire and percent of trees that have fallen in in both the canopy and understorey and assess the height of the different fuel strata according to the Victorian Fuel Hazard Guide [3].

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3 3. Hines, F., Hines, F., Tolhurst, K.G., Wilson, A.A., McCarthy, G.J. (2010) Overall fuel hazard assessment guide. Victorian Government, Department of Sustainability and Environment No. 1742426778 Available at https://www.ffm.vic.gov.au/__data/assets/pdf_file/0005/21110/Report-82-overall-fuel-assess-guide-4th-ed.pdf.

APPENDIX A: METADATA

LEVEL 3

Point Severity Data Field	Unit	Description
Site	Number	Unique site identifier for Level 3 methodology
Site Name	Text	Name of previously established permanent plot (if applicable)
Site Location	m	Location (in Easting and Northing – GDA 1994 MGA Zone 55) of point where data is collected.
Date	Date	The date on which the data was collected
Veg Type	Text	The vegetation type of the site that the data is being collected out
Logging/Disturbance	Text	Details if the site has had a known disturbance and the type and year when that disturbance occurred.
Understorey Crown Scorch	%	Percentage of crown scorch for all understorey trees within 10m radius of site
Canopy Crown Scorch	%	Percentage of crown scorch for all canopy trees within 10m radius of site
Burnt surface	%	Percentage of surface burnt by fire in a 5 m radius of site
Rock Cover	%	Percentage of rock cover in a 5m radius of site
Slope	°	Slope (degrees) of site taken at 10m distance as per methodology
Aspect	°	Aspect (degrees) taken in degrees at 10m distance as per methodology.
Dead	Binary	1=Dead, 0=Alive. Dead is absence of green leaves as per methodology.
Basal	Binary	1=Basal resprouting is present and 0=Basal resprouting absent
Epicormic	Ranking	0-5 scale ranking epicormic resprouting on the vigorous of it. 0 is no epicormic, 1 to 5 is a scale as outlined in methodology
Undamaged	Binary	1=tree/woody stem is alive and with no resprouting, 0=tree is dead/resprouting.
Crown Scorch	%	Percentage of Crown scorch of individual woody stem

Species	Text	Details the species of the woody stem being assessed
Notes	Text	Details any extra notes about the woody stems

LEVEL 2

Sheet Name	Description
Fuel Weights	Masses of dead fine fuels, coarse fuels, and near-surface fuels collected from quadrats
Elevated fuels	Structure, density, and charring of live and dead plants in the elevated layer
Downed wood	Count and diameter of downed logs intersecting fuel transects
Trees	Dimensions, charring, and other severity measures for non-stringy bark trees with >10cm DBH adjacent to fuel transects
Hazard Scores	Qualitative Hazard Scores (Hines et al 2010) and visually estimated structural attributes

Fuels Weights data field	Unit	Description
Date	Date	Date on which observation was collected
Site Name	Text	Name of previously established permanent plot
Transect	Letter	Transect Identifier, see section 9.1 of the Ausplot Survey Manual [2].
Quadrat	m	Location of 1x1m quadrat on transect as measured by distance from the start of the transect Either (7m or 21m)
Type	Categorical	Type of fuel measured
Wet Weight	g	Field weight of given fuel type in quadrat
Dry Weight	g	Oven-dry weight of given fuel type in quadrat
Oven Dried?	Binary	Was the given sample oven-dried? If no, dry weight was calculated as opposed to measured

Elevated Fuels data field	Unit	Description
Subplot	m	Location along transect (in m from the start of the transect) of the subplot in which five plants were measured
Basal Diameter	cm	Diameter at the base of the stem for the given plant
DBH	cm	Diameter of the stem at breast height (1.3m) for the given plant
Height	m	Height of plant
Char Height	m	Highest point of charring on plant stem
Stem Length	m	Length of stem (applicable to tree ferns only)
Burnt Tip Diameter	mm	Average diameter of all charred branch tips between 0.75 and 1.5m above the ground
Canopy Width	m	Estimated width of widest part of the individual's tree crown if projected onto the ground
Canopy Length	m	Estimated width of individual crown perpendicular to above measurement
Life Form	Categorical	Growth form (e.g. shrub, tree, tree fern, etc.) of plant
Live/Dead	Categorical	Is plant alive?
Rectangle Length	m	Length of rectangle surrounding five plants in subplot
Rectangle Width	m	Width of rectangle enclosing 5 plants in subplot
# Stems	Number	Number of stems for the given plant if there are more than 1 at the height at which diameter was measured

Downed Wood data field	Unit	Description
Small Woody Fuel Count	Number	Count of small woody fuels (<7.6cm and >2.5cm diameter) intersecting transect along two 2m subsections as indicated
Large Woody Fuels	cm	Diameters of all large woody fuels (>7.6 cm diameter) intersecting transect.

Trees data field	Unit	Description
Tag #	Number	Number of identification tag nailed to tree

SPP	Categorical	Four letter species code for tree
DBH	cm	Diameter of the stem at breast height (1.3m) for the given plant
Max Scar Ht	m	Highest point of charring on plant stem
Live/Dead	Categorical	Is tree alive
Canopy Scorched %	Percentage	Percent of tree crown that was scorched by fire
Defoliated	Binary	Is the tree defoliated?
Epicormic	Binary	Is there epicormic resprouting on tree?
Basal Regrowth	Binary	Is there basal resprouting on tree?

Hazard Score data field	Unit	Description
Height to Crown Base	m	Height from ground to lowest point on stem at which crown encircles >1/3 of the stem
Bark Hazard	Categorical	Qualitative hazard score for eucalyptus overstorey bark
Elevated Pct. Cover	%	Estimated percent cover of fuels in the elevated layer
Elevated Pct. Dead	%	Estimated percent dead material in the elevated layer
Elevated Ht.	m	Estimated height of the elevated layer
Elevated Hazard	Categorical	Qualitative hazard score for fuels in the elevated layer
Near-Surface Pct. Cover	%	Estimated percent cover of fuels in the near-surface layer
Near-Surface Pct. Dead	%	Estimated percent dead material in the Near-Surface layer
Near-Surface Ht.	m	Estimated height of the Near-Surface layer
Near-Surface Hazard	Categorical	Qualitative hazard score for fuels in the Near-Surface layer
Surface Pct. Cover	%	Estimated percent cover of litter on the forest floor
Surface Depth	cm	Depth of litter on the forest floor as measured at 5 random points within 5m of assessment point
Surface Hazard	Categorical	Qualitative hazard score for the surface fuels

LEVEL 1

Overstorey Severity Data Field	Unit	Description
Site Name	Text	Name of previously established permanent plot
Date	Date	The date in which the survey took place
Surveyor	Text	The person who did the surveying
Tree id #	Number	Details the Ausplot id number of the tree/stem being assessed
Species	Text	Details the species of the tree/stem being assessed, see methodology notes for abbreviations/names used
Dead	Binary	1=Dead, 0=Alive. Dead is absence of green leaves as per methodology.
Canopy Scorch	%	Percentage of canopy scorched for tree being assessed.
Epicormic	Binary	1=epicormic present and 0=epicormic absent
Basal Regrowth	Binary	1=Basal resprouting is present and 0=Basal resprouting absent
Notes, DBH, Char Height	Text/Number	Details any relevant notes taken in field including notes, DBH (cm) if new or unidentified tree and char heights of trees (m).