THEME 2.3- FIRE SEVERITY AND IMPACT

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Subproject: Fire severity statistics

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OVERVIEW

1. Theme

Fire severity and past fire impact

2. Project question or problem statement

What was the impact of past fire type, severity and age on 2019/2020 fire severity, and how was this moderated by fire weather conditions?

3. Key findings

- Statistical modelling was performed using point samples associated with MODIS hotspots for the Gospers Mountain, South Coast and Bees Nest fires, inside and outside post mid-2017 antecedent fire boundaries, with a range of controlling meteorological and topographic covariates (Hammill & Bradstock, 2006). Points were limited to Wet Sclerophyll and Dry Sclerophyll vegetation formations, with vegetation type included as a factor in the model. Past fire ID, nested within 2019/20 fire ground, was included as a random effect.
- A model testing the effect of recent antecedent fire on severity showed points outside recent fires had an 89% probability (CI: 78-94%) of being in the high or severe classes, while points inside recent fires had a 47% probability (CI: 29-65%) of being in the high or severe classes (Figure 1).
- A model testing the effect of the severity of recent antecedent fire showed no strong effect on 2019/20 severity (Figure 2). It should be noted there is a sparsity of severity measures for recent antecedent fires due to the patchy nature of prescribed burns, so sample points

were limited (n = 1883), likely reducing the power of this analysis to detect any past severity effect.

- A model testing the effect of time since last fire on the probability of high and severe categories, post mid-2017, showed a declining effect of antecedent fire over time (Figure 3), with recently burnt areas having a higher probability of burning at a lower severity than locations burnt earlier.
- A model testing the effect of past fire type, (hazard reduction versus wildfire), post mid-2017, showed a greater probability of elevated severity inside hazard reduction burns than wildfires (Figure 4). Additionally, under elevated fire weather conditions (FFDI), probability of elevated fire within past boundaries remained low within wildfire boundaries, but hazard reduction burns had a reduced ability to reduce severity under elevated FFDI (Figure 5).

4. Significance of findings in context of previous studies

An analysis of the effect of prescribed burning on the severity of the 2003 Alpine fire in eastern Victoria (Tolhurst & McCarthy 2016) showed that past prescribed burning reduced fire severity and assisted in suppression, but this effect was strongest during more moderate weather conditions, and that prescribed burning had little impact when the Forest Fire Danger Index (FFDI) was above 50. Tolhurst & McCarthy (2016) also found that prescribed burns less than 3 years old had the greatest impact on severity. Our analysis was limited to fires from mid-2017 with this in mind, along with a lack of consistent Sentinel-2 satellite imagery which limited application of the FESM severity algorithm prior to this date. The statistical analysis presented here concurs with these earlier findings; the presence of recent fire reduced severity, but this effect was greater for wildfires than hazard reduction burns, and hazard reduction burns had a reduced effect under more severe fire weather conditions. A review of the effectiveness of prescribed burning globally (Fernandes & Botelho 2003) concluded that the effectiveness of prescribed burning is strongly limited by fuel accumulation rates, with forests rapidly accumulating fuels within the first 2-4 years post-treatment, and with prescribed burning most effective in heterogenous landscapes with low likelihood of extreme fire weather conditions. In these case-study fires, periods of extreme fire weather, along with the inaccessible terrain that limited suppression ability and allowed for long fire-runs, likely limited the effectiveness of prescribed burning in affecting severity in many cases. The statistical modelling performed so far shows a decline in severity reduction by past fire with time, even at only three years after treatment.

5. Limitations and remaining knowledge gaps

- The satellite-based severity classification has an inherent limitation in detecting fire effects through dense canopies. There is also a lower limit to the sensitivity and resolution of satellite-based estimation in mapping patchy low severity ground fires, which may appear as unburnt. The FESM algorithm does not currently include any training data from the 2019/2020 fire season, but there are plans to revise and improve the severity classification using additional training data derived from interpretation of high-resolution post-fire aerial photography of this season's fires.
- The analysis was limited by the patchy nature of past severity measurements within hazard reduction burns, resulting in low statistical power to detect this effect. As satellite-based severity measurements become standard practice, and are increasingly applied to both hazard reduction burns and wildfires, further research will serve to improve our understanding of the effect of prescribed fire treatment on reducing wildfire severity.

6. Implications for fire management

- Overall, the presence of recent past fire reduces fire severity, but this effect reduces rapidly with time since fire. This statistical analysis was able to highlight the relative effectiveness of prescribed burns compared to wildfire in reducing subsequent wildfire severity. Prescribed burns do reduce the severity of subsequent wildfires; however, this effect is less than that of wildfires, it is short lived, and it is less effective under severe fire weather conditions.

7. Figures

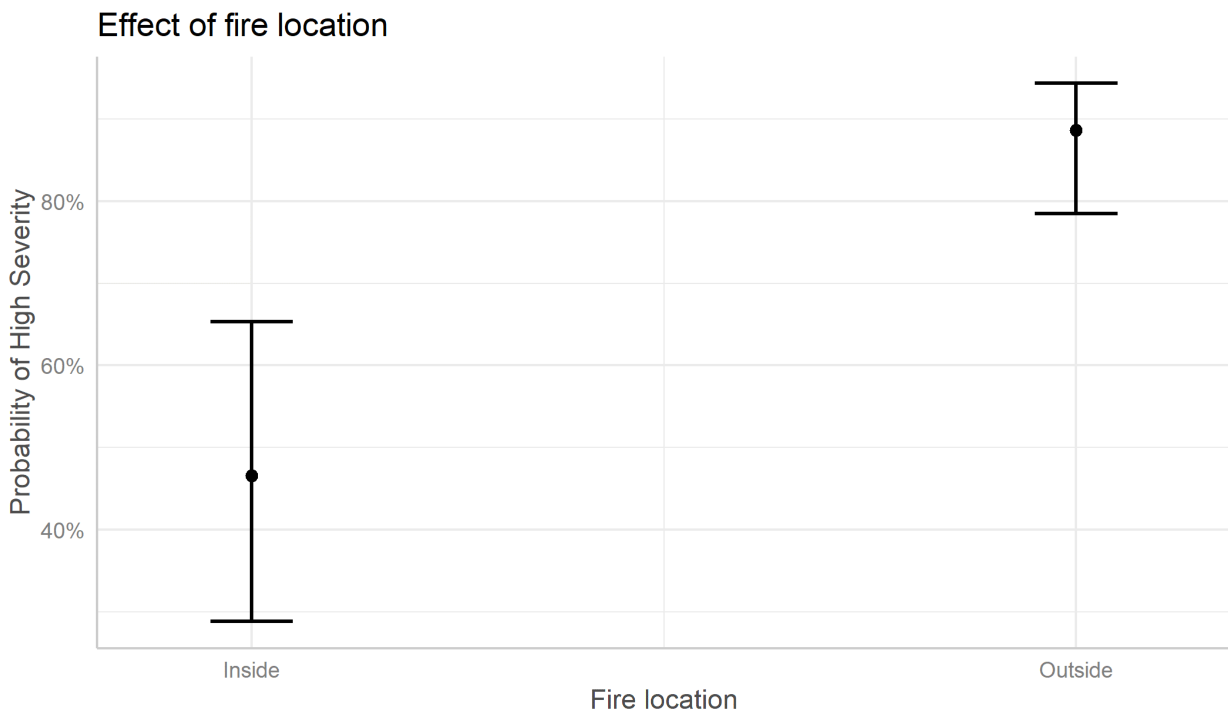

Figure 1. Effect of past fire presence (inside or outside past fire) on the probability of high-severe fire severity category in 2019/20.

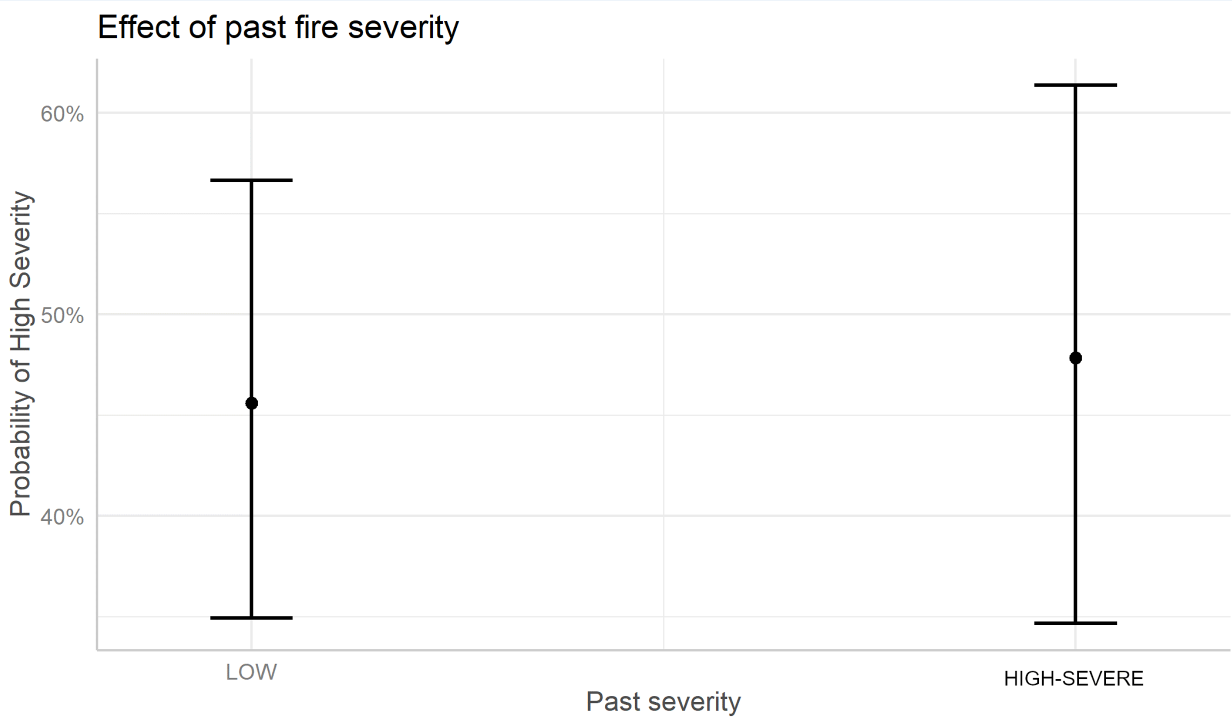

Figure 2. Effect of past fire severity (low vs. high-severe) on the probability of high-severe fire severity category in 2019/20. This effect was not statistically significant.

Figure 3. Effect of time since past fire on the probability of high-severe fire severity category in 2019/20.

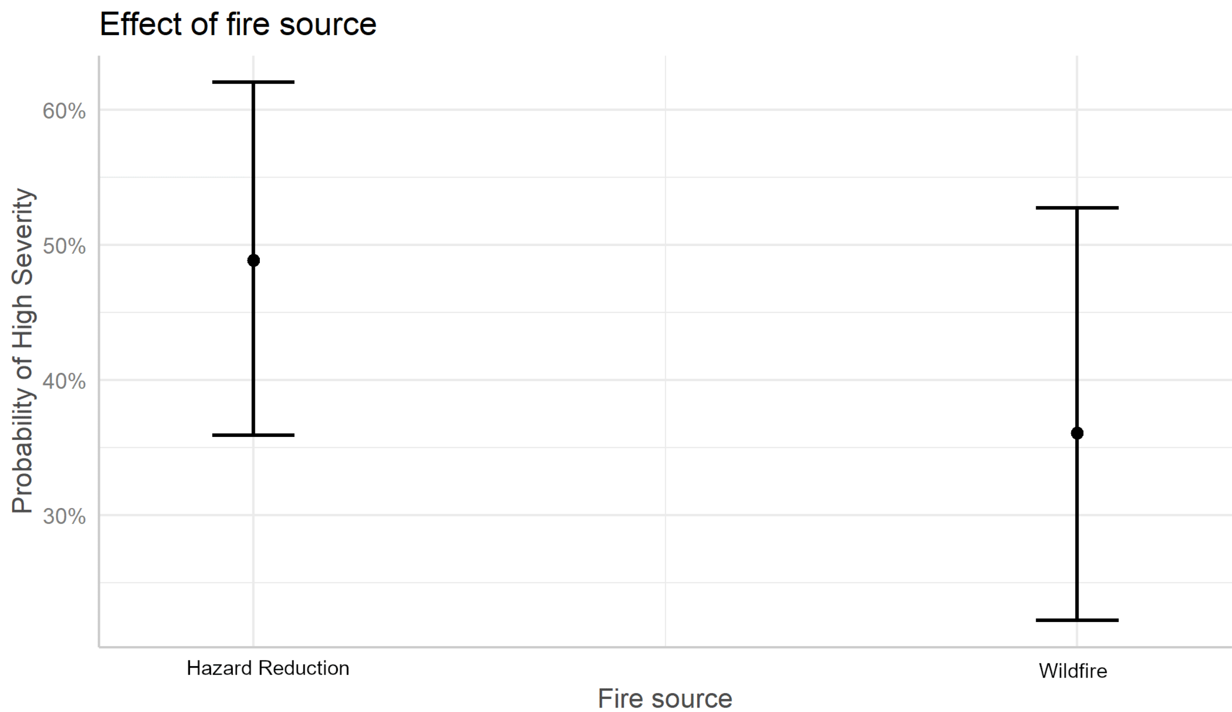

Figure 4. Effect of past fire type on the probability of high-severe fire severity category in 2019/20.

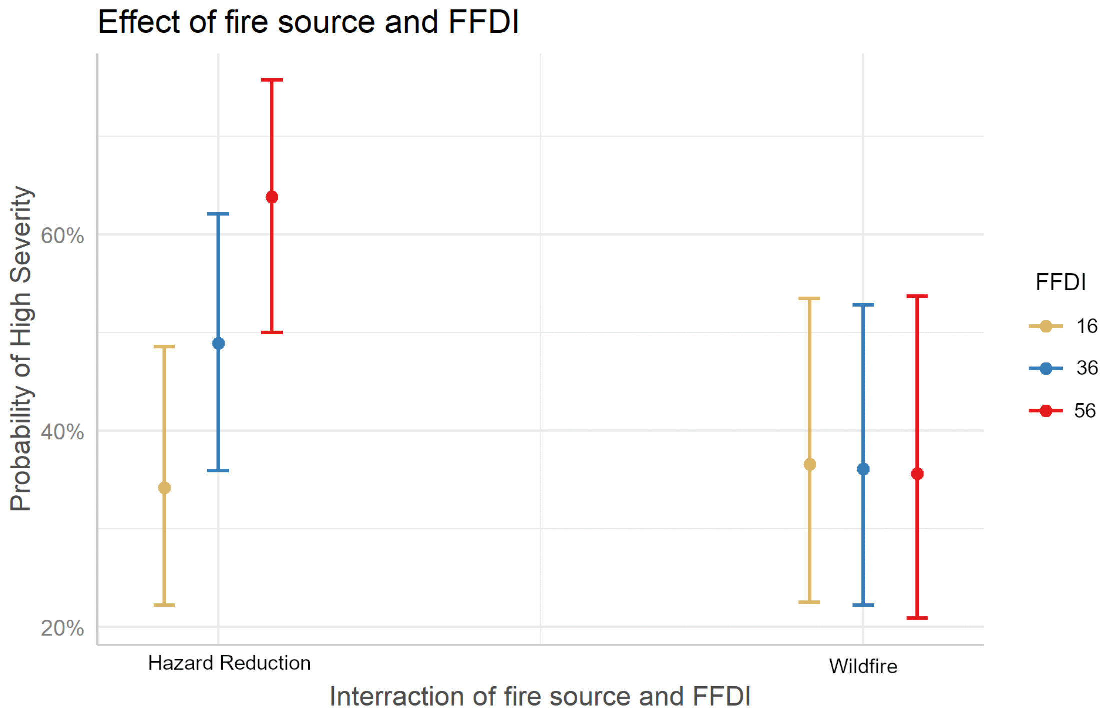

Figure 5. Interaction of Forest Fire Danger Index (FFDI) on with past fire type on the probability of high-severe fire severity category in 2019/20.

8. Key reference list

Fernandes, P. M., & Botelho, H. S. (2003). A review of prescribed burning effectiveness in fire hazard reduction. *International Journal of wildland fire*, *12*(2), 117-128.

Gibson, R., Danaher, T., Hehir, W., & Collins, L. (2020). A remote sensing approach to mapping fire severity in south-eastern Australia using Sentinel 2 and random forest. *Remote Sensing of Environment, 240*, 111702.

Hammill, K. A., & Bradstock, R. A. (2006). Remote sensing of fire severity in the Blue Mountains: influence of vegetation type and inferring fire intensity. *International Journal of Wildland Fire*, *15*(2), 213.

Nolan, R. H., de Dios, V. R., Boer, M. M., Caccamo, G., Goulden, M. L., & Bradstock, R. A. (2016). Predicting dead fine fuel moisture at regional scales using vapour pressure deficit from MODIS and gridded weather data. *Remote Sensing of Environment*, *174*, 100-108.

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9. Appendix

Methods

- Past fire boundaries for New South Wales were obtained from the NSW RFS, for determining the location and time of previous prescribed and unplanned fires.

- The FESM fire severity mapping algorithm (Gibson et al. 2020) was applied across all fire grounds in New South Wales. In addition, the algorithm was applied within past prescribed burn and unplanned fire boundaries for previous years going back to 2017, the year in which the Sentinel-2 satellite imagery required for the algorithm became available. The highest FESM category, representing canopy consumption, is referred to as “Severe” in this report; it may be referred to as “Extreme” elsewhere.

- Vegetation formation mapping was obtained from the NSW State Vegetation Type Map, current to January 2019, for intersection and summarizing severity classes.

- Fire progression polygons were obtained from the NSW RFS and were assigned distance-weighted mean FFDI values derived from Bureau of Meteorology weather stations within 100km for each timestep. FESM severity for each cell was attributed with the FFDI of the isochron it fell within, in order to summarize severity category by FFDI.

- Recent (mid-2017) fire boundaries were buffered by 2km, and the area inside past fires regarded as inside points, and those in the external buffer as outside points.

- Sample points were randomly generated at a density of two points per hectare across the inside and outside areas. The suitability of this sampling density was determined by inspection of the semivariogram of 2019/20 season severity across sample points. Sample points were attributed with 2019/2020 fire severity, past fire severity, past fire type, topographic position, roughness, slope, and northerly aspect index calculated from a 30m digital elevation model, vegetation formation, and dead fuel moisture content (Nolan et al. 2016).

- Generalized linear mixed-effect binomial models, with past fire ID within 2019/20 fire ground ID include as random effects, were used to test three hypotheses;

  1 – Fire severity was lower inside past fire boundaries than outside, with a reduced effect under elevated FFDI conditions, controlling for other covariates

  2 – Fire severity was lower where past fire was more severe, controlling for other covariates

  3 – Fire severity was lower where the past fire was more recent, with a reduced effect under elevated FFDI conditions, controlling for other covariates

4 – Fire severity was lower where the past fire was a wildfire, compared to a hazard reduction burn, with a reduced effect of hazard reduction burns under elevated FFDI conditions, controlling for other covariates.

- Models 1 used 73,288 sample points, while models 2, 3 and 4 used a subset of 1,883 points where past fire severity was known.

- AIC-based model selection was used to identify the most parsimonious variable suite for each hypothesis. The severity contrast in the binomial models was between the low severity category, and the combined high and severe categories. Unburnt and moderate severity points were excluded. All statistical modelling was carried out in R version 4.0.0 using the lme4 package.