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LETTER TO THE EDITOR

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Causes and consequences of eastern Australia's 2019–20 season of mega-fires

The 2019–20 fire season in eastern Australia is attracting considerable national and international attention. At the time of writing c. 3.8 million ha of mainly temperate forest have burnt in the state of New South Wales (NSW; NSW Rural Fire Service, 29/12/2019; Figure 1a). Major blazes are also occurring in other states, including over 0.5 million ha in the state of Victoria (situated on the southern border of NSW). This exceeds the area burnt in the 1939 Black Friday fires (c. 2 million ha), which were the largest fires recorded in temperate Australian forests since European settlement (www.ffm.vic.gov.au). Notably, the Gospers Mountain fire on the fringes of Sydney is over 508,000 ha (as of 29/12/2019; Figure 1a), and is still uncontained, having traversed the width of the Blue Mountains World Heritage Area and now merged with other fires near the coast. It is important to note that this record-breaking fire season is not yet over, with the south-eastern Australian fire season typically extending to the end of summer (February). Multiple large fires are still burning across NSW and in other states, with the situation rapidly changing.

For landscape-scale wildfires to occur four conditions are needed: (a) the presence of spatially continuous fuel (i.e. plant biomass); (b) that fuel being dry enough to burn; (c) an ignition source (e.g. lightning or anthropogenic causes); and (d) weather conditions favourable to fire spread (Bradstock, 2010). In high biomass ecosystems, such as temperate Australian forests, spatially continuous arrays of fuel are generally present, except for in the first several years following fire or other disturbance, when fine fuel loads can be substantially reduced. Thus, the second precondition, fuel dryness, is a key constraint on the occurrence of large wildfires in this region (Nolan, Boer, Resco de Dios, Caccamo, & Bradstock, 2016).

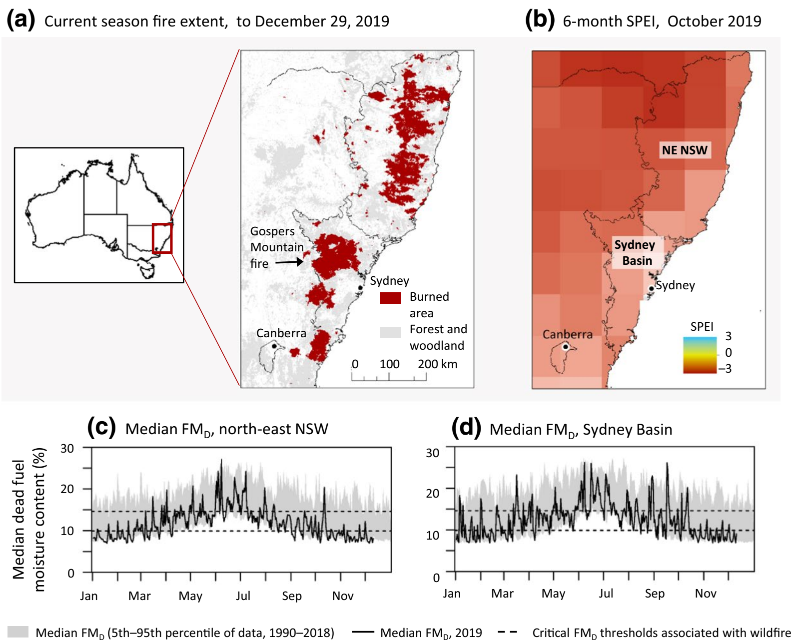

FIGURE 1 (a) Burned areas in the 2019–20 fire season (data from the New South Wales [NSW] Rural Fire Service, 29/12/2019), and extent of forests and woodlands (Australian Department of Agriculture and Water Resources, 2019). Note, burned area mapping is live operational data and will be subject to further verification at the end of the fire season. (b) 6 monthly standardized precipitation evapotranspiration index in October, 2019, (SPEI; Vicente-Serrano et al., 2010; data obtained from https://spei.csic.es/index.html). (c, d) Median values of estimated daily minimum dead fuel moisture content (FM$_D$) across north-east NSW and the Sydney Basin. Values for the current fire season are shown in the solid line, as are the range of values between 1990 and 2018 (5th–95th percentile of data shown). The upper dashed horizontal line indicates the value of estimated FM$_D$ at which forests are available to burn, while the lower horizontal dashed line represents the estimated FM$_D$ value associated with the historical occurrence of large wildfires across south-eastern Australia (Nolan, Boer, et al., 2016)

Low fuel moisture content, particularly in live fuels (i.e. foliage and twigs) occurs during drought. Drought also triggers leaf senescence and shedding in eucalypt forests, resulting in an increase in surface fine fuel loads, which can increase the rate of fire spread (Ruthrof et al., 2016). Importantly, during drought and extreme fire weather, normally damp gullies and rainforest patches are unlikely to provide their usual impediment to the spread of fire across the landscape (Collins, Bennett, Leonard, & Penman, 2019). Eastern Australia has been experiencing severe drought in the lead up to and during the current fire season. In particular, much of north-eastern NSW has had the lowest rainfall on record and above average temperatures over the 6 months to November 30, 2019 (www.bom.gov.au/climate/maps/). The standardized precipitation evapotranspiration index (SPEI; Vicente-Serrano, Beguería, & López-Moreno, 2010), which is a simple climatic water balance model, similarly shows that drought across eastern NSW has been severe (Figure 1b; data from https://spei.csic.es/index.html). SPEI values range from −3 to 3, with negative values representing dry conditions, and positive values representing wet conditions. In north-east NSW, the SPEI for October 2019, calculated on a 6 month analysis window (with a calibration period from 1950 to 2010), was −1.8 on average across the region (ranging from −2.6 to −1.1) which corresponds to a 0.04 probability of occurrence of these dry conditions over the calibration period. In the Sydney Basin, the most populated part of NSW, October SPEI was −1.2 on average (ranging from −1.8 at the location where the Gospers Mountain fire originated to −0.6 near the coast), which corresponds with a 0.11 probability of occurrence of these dry conditions.

For fine dead fuels (i.e. litter), moisture content is largely driven by atmospheric conditions and by soil water content, for fuels in close contact with the soil (Matthews, Sullivan, Watson, & Williams, 2012; Resco de Dios et al., 2015). We examined temporal trends in dead fuel moisture content using a model based on vapour pressure deficit (Nolan, Dios, et al., 2016; Resco de Dios et al., 2015). Data were obtained from the Bureau of Meteorology's Australian Water Availability Project (Jones, Wang, & Fawcett, 2009). We found that estimated dead fuel moisture content was mostly at the lower range of historical values throughout 2019 (Figure 1c,d). Furthermore, from September/October onwards, estimated dead fuel moisture content was mostly below critical threshold values associated with the historical occurrence of large wildfires in south-eastern Australian forests (Nolan, Boer, et al., 2016). The occurrence of drought and low values of dead fuel moisture content primed the landscape for the unprecedented fires now burning under unrelenting severe fire weather conditions (http://www.bom.gov.au/climate/current/statements/scs72.pdf).

Impacts from this fire season on forests are difficult to assess until the season draws to a close, as further areas may be subject to fire, and postfire recovery depends on the state of the postfire climate. The eucalypt forest communities that cover most of the fire affected area are resilient to high severity wildfire (Collins, 2020). These forests generally recover from fire by resprouting new foliage. Whether postfire resprouting will be affected by the severe drought, for example through depletion of carbohydrate reserves, is uncertain. Fire-sensitive forest communities, such as remnant rainforests, have persisted in a fire-prone *Eucalyptus* matrix over geological timeframes within areas where high fuel moisture content is usually maintained throughout the fire season (Bowman, 2000). Extreme drought can dry fuels below critical thresholds within these fire refugia, allowing the encroachment of wildfire into these less fire-resilient vegetation communities (Collins et al., 2019). The 2019–20 fires have burnt significant areas of the Gondwana Rainforests, Australia World Heritage Area (potentially up to ~50% of its current distribution), posing a major threat to this globally significant vegetation. The impact of the fires on these rainforests, and many other fire-sensitive taxa, will become more apparent once necessary fire severity mapping and postfire field surveys are conducted.

The current 2019–20 fire season in Eastern Australia is unprecedented in the size and number of fires burning in temperate Australian forests. These fires are an indication that changes to the fire regime predicted under climate change, including more frequent and more severe fires (Bradstock, 2010; Clarke & Evans, 2019), may now be occurring.

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