Forest recovery in NSW following 2019-20 fires and preceding drought

Coastal IFOA Monitoring Program

This note summarises analysis of field survey and remote sensing data to quantify the impacts of the 2019-20 fires, the preceding drought and subsequent high rainfall on forest survival and structural recovery in coastal NSW forests. This work was carried out by researchers from the Hawkesbury Institute for the Environment at Western Sydney University (WSU), in collaboration with remote sensing research scientists from NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW), as part of the Coastal Integrated Forestry Operations Approvals (IFOA) Monitoring Program.

The study found that overall levels of tree mortality, topkill and recruitment post-2019-20 were similar, however the forest area affected was far greater and led to higher levels of tree death and tree crown death at a regional scale. High levels of tree and tree crown death were generally restricted to areas burnt at high or extreme severity. Tree and tree crown death were also more likely for small and large trees, and trees with pre-existing basal injuries. The compound impact of the preceding drought and 2019-20 fires may have led to demographic change to forests. High seedling numbers and growth in the years following the fires were likely due to above-average rainfall. It has been widely reported by other studies that Australian forest fire regimes are changing, with increasing frequency, intensity and extent impacting forests.

Major fires throughout the Coastal IFOA region during 2019-20 affected around 40 percent of native forests on all tenures. These forests were suffering from widespread drought prior to the fires. Above average rainfall in the years following the drought and fires resulted in broadscale 'regreening' of the forest.

The aim of this review was to assess rates of tree mortality, topkill, and seedling recruitment, across a range of fire severity, forest types and substrates. Further analysis compared field data with vegetation recovery indices, with the aim to improve interpretation of remote sensing estimates of post-fire biomass recovery. The authors provide estimates of potential structural changes in wet and dry sclerophyll forests (the predominant forest types in the Coastal IFOA region) as a function of granite or sandstone substrate and fire severity.

Two independent field datasets from WSU and the Forestry Corporation of NSW (FCNSW) were analysed in the review. These comprised 89 sites within the National Park estate burnt at high and extreme severity and 261 sites within state forests in the Coastal IFOA region burnt across the range of

Tree mortality – complete death of tree

Topkill – complete death of tree crown, or loss of most above-ground biomass and basal-resprouting only

Recruitment – growth of new tree seedlings following fire or other disturbance

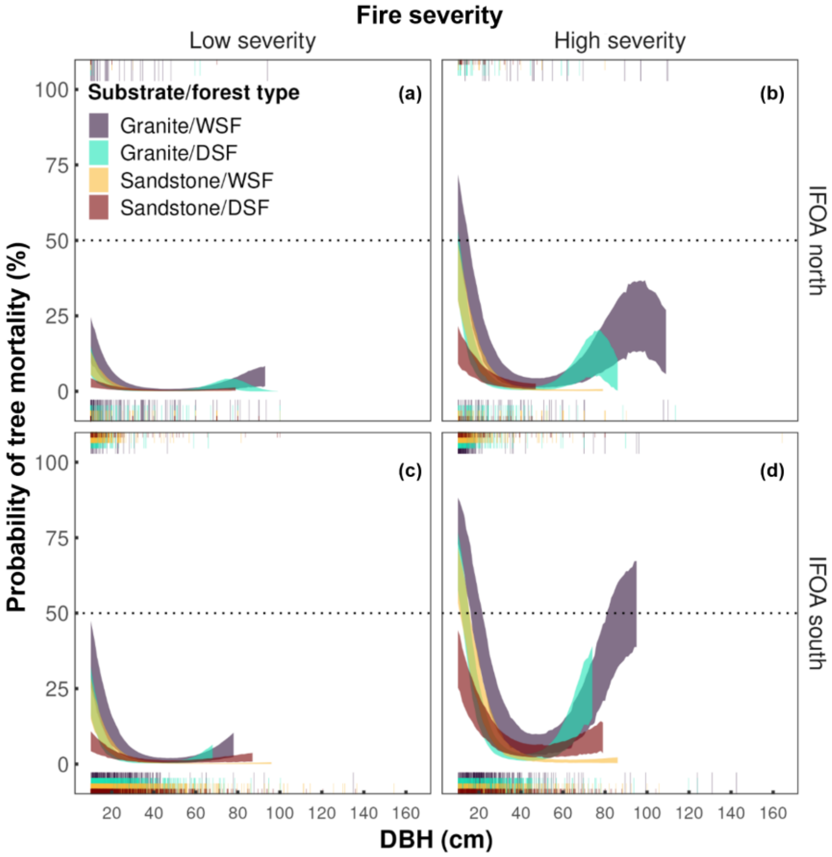
Re-greening – increase in amount and greenness of vegetation cover using satellite-based reflectance index

Dry sclerophyll forest – vegetation with hard leaves adapted to long dry periods and heat typically in low rainfall or soil fertility areas

Wet sclerophyll forest – vegetation with hard leaves adapted to long dry periods and heat typically in high rainfall and moderate soil fertility areas fire severities. The study used two indices developed by remote sensing research scientists from NSW DCCEEW, the post-fire biomass recovery index and the limited or delayed recovery index.[1]

2019-20 fires had a similar impact to previous fire seasons across a greater forest extent

The study found that compared to previous fire seasons the overall levels of tree mortality, topkill and recruitment following the 2019-20 fires were similar, however the geographic extent of forest affected was far greater, leading to higher number of overall tree deaths at a regional scale. In addition, there was widespread tree mortality and topkill in both the smallest and largest trees in forests burnt at high and extreme severity. This is reflected by the 'u'-shaped response curves in **Figure 1**. The authors suggest this response may be due to the combined impact of drought and fire.



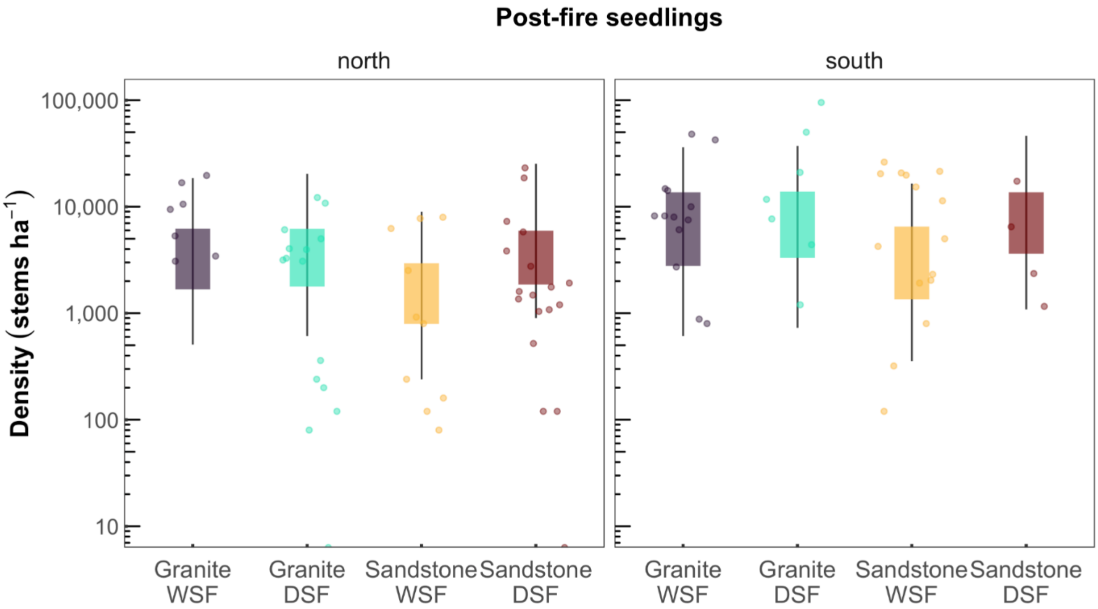
Note: Coloured ribbons represent 50% credible intervals. Predictions for each substrate/forest type are constrained to within the 99th percentile of the observed DBH range for each plot window. Rug plots (narrow coloured vertical bars) at the top (dead trees) and bottom (live trees) of plot windows represent the observation density across the complete range of DBH values used to inform the model. WSF = wet sclerophyll forest, DSF = dry sclerophyll forest. 'u'-shaped tree mortality response curves can be seen in (b) and (d).

Figure 1: The probability of tree mortality following the 2019-20 fires and preceding drought at FCNSW sites by CIFOA region, fire severity, diameter breast height (DBH) and substrate/forest type

Field surveys revealed that high levels of mortality and topkill were generally restricted to areas burnt at high or extreme fire severity. Trees with pre-existing basal injuries were substantially more likely to experience mortality and topkill in forests burnt at high and extreme severity. Additionally, forests growing on relatively fertile granite-derived soils generally experienced higher levels of tree mortality and topkill than forests growing on lower-fertility sandstone soils.

Forest response was mixed post-fire

Field surveys recorded the number of post-fire seedlings and identified a wide range of seedling species.[2] The study found high levels of post-fire seedling recruitment across all surveyed substrates and forests, as shown in **Figure 2**. High levels of seedling recruitment suggest that above-average rainfall in the years following the 2019-20 fires may have enhanced recruitment, particularly on lower fertility soils where post-fire recruitment has historically been reported to be relatively low.



Note: WSF = wet sclerophyll forest, DSF = dry sclerophyll forest. The points show raw post-fire seedling density and box plots show the predicted density modelled at a regional scale.

Figure 2: The density of post-fire seedlings modelled for Coastal IFOA regions by substrate and forest type

Delayed recovery signals were significantly more prevalent at sites with elevated rates of mortality and topkill, and in wet sclerophyll forests on granite substrate where the preceding drought may have made forests less resilient to further disturbance. Higher recovery index values were associated with dense Acacia regrowth, high or extreme fire severity, at drier sites, and in dry sclerophyll forests on sandstone substrate that are likely more resilient to disturbance.

Field surveys did not provide repeated site measures over multiple consecutive years, precluding a comprehensive field validation of the remote sensing method. Nonetheless, the remote sensing assessment showed strong alignment with field data analysis results.

Combined impact of drought and fires may cause long-term shifts in forest structure

The authors suggest that the severity of the combined drought and fires may have pushed some forests beyond a hypothetical disturbance threshold that caused large, fire-resistant trees to die, particularly in wet sclerophyll forests. This may have resulted in a demographic shift in some forests toward mid- and smaller-sized trees. For example, around 22-28 percent of large trees (e.g. >80 cm diameter at breast height, DBH) in wet sclerophyll forests were likely to be dead overall, and this increased to more than 50 percent for trees that had pre-existing basal fire scar injuries (i.e. around half of all mature trees).

One potential consequence of the death of large, old trees is that many could have been hollow-bearing and thus important for supporting hollow-dependent animals. However, if large, old trees die or are damaged but remain standing they could continue to provide suitable hollows for animals in the medium term.

Another potential consequence of a demographic shift toward mid- and smaller-sized trees is that juvenile trees are less resilient to fires and more frequent fires could prevent these trees from maturing to fire-tolerant size classes. This could also impact recruitment if tree species are unable to regrow from lignotubers or seed, potentially leading to a change in tree species composition or forest structure.

The analyses were limited to wet and dry sclerophyll forests growing on sandstone and granite substrates, which represent 44 percent of state forests within the Coastal IFOA region. Some areas were extensively impacted by high and extreme severity fire, particularly in the south (e.g. 35-45 percent). The authors inferred that similar forests across all tenures within the Coastal IFOA region, particularly in the south, would likely have experienced substantial mortality and topkill if exposed to high and extreme severity fire, and will be in a state of recovery for many decades. This prolonged state of recovery is due to structural changes primarily caused by losses of large trees. However, the magnitude of structural change is likely to vary with substrate/forest type and the proportion of trees that had basal injuries at the time of the fires.

There is a growing body of evidence suggesting habitat implications for NSW forests

The ‘u’-shaped topkill and mortality response curves for smallest and largest trees found in this review, have also been found in other southeast Australian studies. For example, the same effect was found by Bennett et al (2016)[3] from the 2009 fires in Victoria and by Watson et al (2020)[4] from prescribed burning at long-term experimental sites. While there are only a few southeast Australian studies that have observed this ‘u’-shaped mortality curve in eucalypt dominated forests, there are other studies around Australia[5, 6, 7] and international literature describing this same response to disturbance.[8, 9, 10]

Understanding demographic changes in response to disturbance is important for predicting potential implications for biodiversity and carbon storage in forest ecosystems.[11] The findings presented here in respect to topkill and mortality for the smallest and largest trees are important to consider along with recent research into fire extent, severity and frequency in Australia. The long-term forest fire research by Canadell et al (2021),[12] which assessed 90 years of ground-based data, identified that the area of forest burnt and fire frequency in Australia is increasing. Abram et al (2021)[13] stated the 2019-20 fires were consistent with scientific assessments that human-caused climate warming is virtually certain to increase the extent, duration, frequency and intensity of forest fires in southeast Australia. Across the Coastal IFOA region, research by the University of Wollongong commissioned under the CIFOA monitoring program found that there were substantial changes to fire regimes resulting from the 2019-20 fires including increases in the proportion of area burnt at intermediate and high frequency.

In addition to demographic changes,[14] other studies have reported impacts to habitat features from changing fire regimes. For example, the number of hollow-bearing trees will decline following frequent and higher severity fires where trees collapse, and where there are not enough remaining mature trees in which fires could promote the development of hollows.[15] Other research suggests hollow-bearing trees that survived the 2019-20 wildfires have the potential to form new hollows faster compared to undisturbed mature trees. This suggests that while post-fire nesting spaces may be reduced at the tree scale, hollow-bearing trees persist as habitat legacies at the stand scale.[16] Similarly, early research by Trouve et al (2024)[17] commissioned under the CIFOA monitoring program suggests the likelihood of hollow formation is higher in larger fire-affected trees and further analysis has been commissioned to enhance this research with additional datasets.

The body of evidence supports further consideration and investigation into implications for forest dependent flora and fauna reliant on various growth stages, and the shelter and feed resources they provide.

Monitoring is essential to understand impacts of past and future fires

The review provides three recommendations to guide future survey methods:

- on-going *in situ* forest monitoring to detect any further mortality and track post-fire recruitment
- on-going monitoring of forest recovery by remote sensing and further research and development of associated remote sensing methods
- collection of additional information in Forestry Corporation of NSW forest surveys.

More information

This work is part of the monitoring forest structure and health strategy within the Coastal IFOA monitoring plan. The report detailing the project findings can be found on the Commission's website.

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