THEME 3B.4- BIODIVERSITY AND ENVIRONMENTAL IMPACTS

Theme Leader: Mark Ooi

Subproject: Ecosystem impacts case study

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OVERVIEW

1. Theme

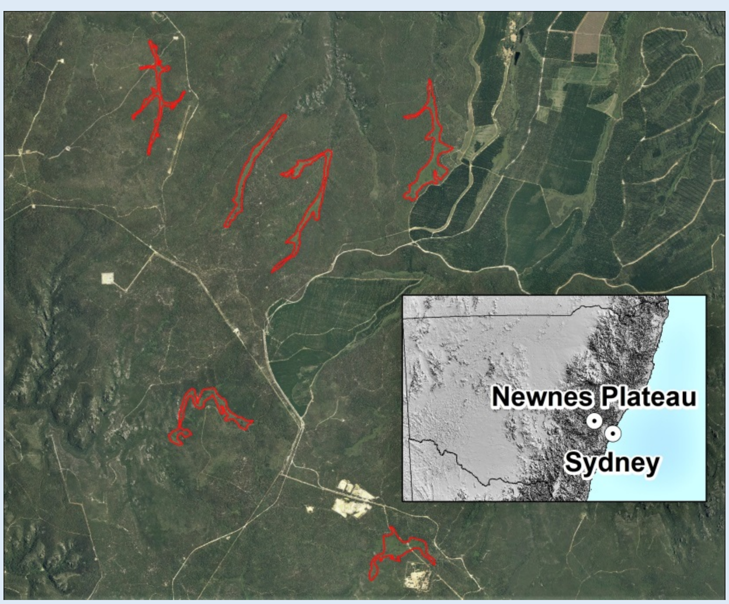
Biodiversity and Environmental Impacts

2. Project question or problem statement

How did prior disturbance affect ecosystem resilience to bushfires?

3. Geographic location

Case study of peatland ecosystems (mapped in red) on the Newnes Plateau, Blue Mountains, Sydney Basin bioregion. These peatlands are listed as an Endangered Ecological Community under the NSW *Biodiversity Conservation Act 2016* (NSW Scientific Committee 2011) and the Australian *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth Threatened Species Scientific Committee 2005).



4. Key findings

- Landscape-scale hydrological changes associated with underground mining eroded the resilience of peatland ecosystems to bushfires.
- Peatlands are rare ecosystems in Australia, and critical to hydrological functions of water storage catchments, carbon sequestration, as well as habitats for unique biodiversity (Young 2017; Krogh 2007; Cowley and Fryirs 2020).
- Relatively undisturbed peatlands were resilient to bushfires, retaining most of their peat and plant species (Figures 1 and 2). They are exhibiting rapid post-fire recovery, with substantial vegetation cover returning within c. 10 weeks of severe fires that consumed all surface litter, aerial foliage and fine branches. Rapid vegetation recovery in these ecosystems buffers against erosive rainfall events and provides post-fire refuges with food and shelter for a range of fauna.
- By comparison, peatlands associated with prior longwall extraction of underground coal underwent ecosystem collapse, remaining largely unvegetated 10 weeks after fire with a high level of peat loss, a substantial reduction in species richness and a shift in species composition (Figures 1, 2 and 3).
- Ecosystem collapse was likely a consequence of irreversible changes to groundwater, substrate permeability and surface morphology, brought about by prior underground longwall mining (Krogh 2007; McNally and 2007; Janowski et al. 2008; Commonwealth of Australia 2014). These changes resulted in reduced retention of soil moisture, predisposing peat and vegetation to extreme consumptive impacts of fire, which killed plant recovery organs and seed banks. These resilience traits underpin the regeneration capacity of the ecosystem and are normally insulated from lethal bushfire heat within the moist peaty substrate.
- This case study provides an example of how prior and post-fire conditions may exacerbate impacts of bushfires on environmental assets and, conversely, how resilience to bushfires might be maintained by avoiding or minimizing exposure to compounding threats. Other examples include: i) exposure to pre-fire or post-fire droughts; ii) short intervals between preceding fires (i.e. contributions to high fire frequency); iii) post-fire interactions with invasive predators and herbivores; iv) interactions between fires and disease; v) high fire

severity; vi) post-fire weed invasion; vii) processes that increase risks of post-fire erosion or pollution.

5. Significance of findings in context of previous studies

The findings of this case study are consistent with a review of mitigation and remediation techniques for peatlands in the Sydney Basin (Commonwealth of Australia 2014), which found no evidence that hydrological changes related to longwall mining could be reversed. Globally, the study of interactions between fire, environmental change and ecosystem resilience is in its infancy. Interactions between fire and hydrological change have not previously been explored in Australian peatlands.

6. Limitations and remaining knowledge gaps

Sampling has so far been limited to short time frames (10 weeks post-fire) and modest sample sizes (7 peatlands). While further sampling is planned, these conclusions are expected to be robust given the magnitude of effects and the irreversibility of the identified mechanisms that underpin the observed response. The general inference that prior degradation or coincident threats erode ecosystem resilience would benefit from testing in other ecosystem types.

7. Implications for fire management

Impacts of large bushfires on biodiversity, ecosystem services and other high-value environmental assets could be avoided or minimized by reducing other causes of ecosystem degradation to maintain natural resilience. This requires landscape- and regional-scale environmental planning to identify and protect sensitive assets, forecasting to assess risks, and enhanced response readiness.

For ecosystems in which resilience has already been compromised, reducing the risk of fire may enable resilience to recover, depending on the nature and reversibility of degradation.

8. Figures

Figure 1. Peatlands on Newnes Plateau taken on 5 March 2020, 10 weeks after fire. Above: Functional peatland at Marangaroo Creek (outside footprint of prior underground mining). Below: Collapsed peatland at Carne Creek West (within the footprint of prior underground mining).

Figure 2. Interactive effects of fire and hydrological change on Endangered peatland ecosystems (Newnes Plateau Shrub Swamp) in the Blue Mountains after the 2019-2020 bushfires. Bars show responses of the valley floors (unhatched) and valley sides (hatched) within swamps that were outside (green) and within (yellow) the footprint of prior underground longwall mining. (a) Fire severity. (b) Peat loss. (c) Post-fire recovery of ground vegetation. (d) Vascular plant species richness. See Methods for details.

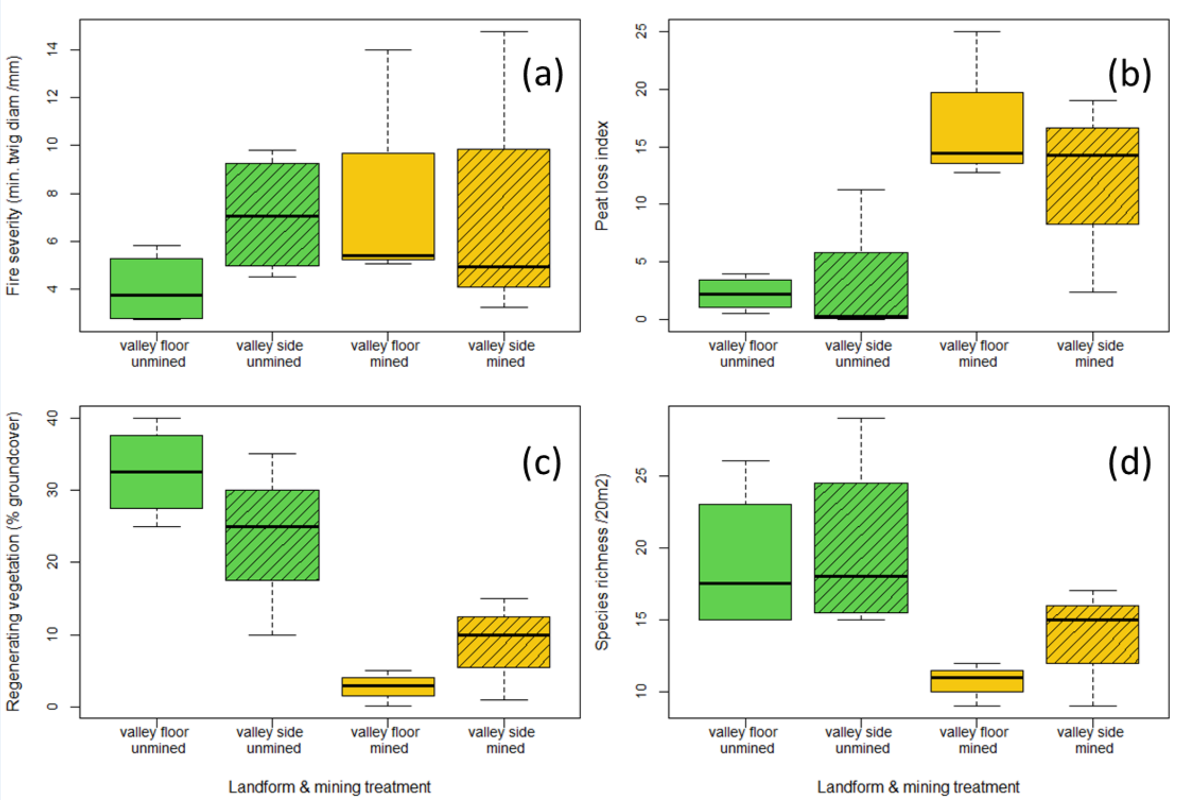
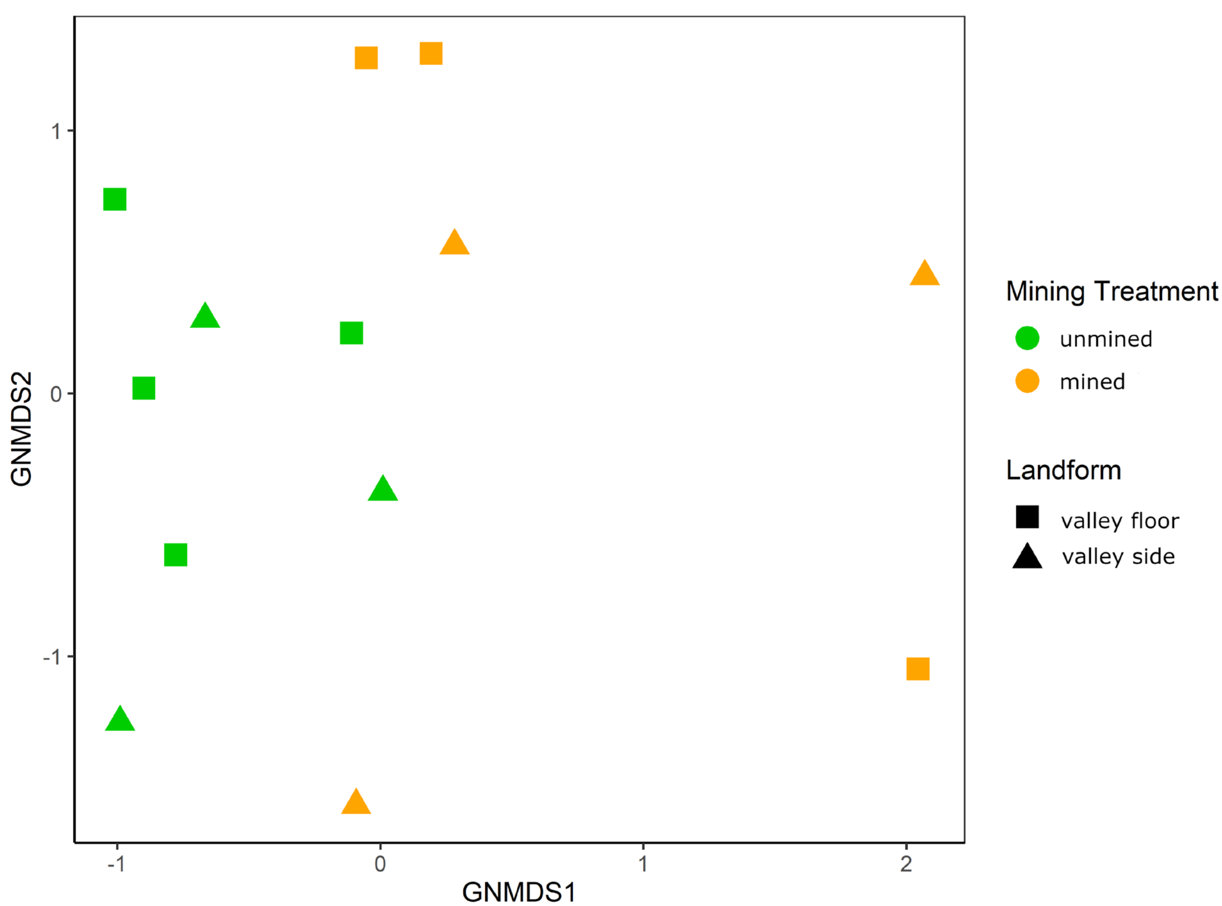


Figure 3. Ordination plot showing differences in plant species composition of post-fire peatland vegetation in Newnes Plateau Shrub Swamps recorded 4-6 March, 10 weeks after fire. Axes are scaled to half-change units. Samples close together on the ordination plot have similar species composition. Results show segregation representing large differences in species composition between swamps within the underground mining footprint (dispersed on right) and those outside (clustered on left).



9. Key reference list

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10. Appendix 1

Methods

Sampling

Seven peatland swamps were selected for survey on the Newnes Plateau including three within the footprint of past underground longwall coal mining (Carne West, Gang Gang East, Gang Gang West) and four outside any longwall mining footprint (Sunnyside, Happy Valley, Broad and Marangaroo), which serve as reference sites. As far as possible, sample sites were aligned with sample sites other monitoring programs. Sampling was carried out during 4-6 March 2020, approximately 10 weeks after bushfires spread through the area on 16 December 2019.

Within each swamp two transects of contiguous 1 x 1 m quadrats were established parallel to the swamp drainage line. One transect in each pair was placed on the valley floor and one on the valley side to sample the range of hydrological conditions and soil types within the peatlands. In general, valley floors experience more prolonged waterlogging, and have deeper soils with higher organic carbon content and lower mineral sediment content than valley sides.

In each of the 14 transects, fire severity was estimated by measuring the minimum diameter of twigs (N=10) on burnt remains of shrubs within 1 m of the ground surface, based on the method developed by Wight et al. (1999). The maximum depth of peat consumed by fire was estimated by measuring the distance between the ground surface and the inferred pre-fire peat surface based on exposed stems and roots of shrubs remaining in situ. The spatial extent of peat consumed by fire was estimated visually as a percentage of surface area across the 20 x 1 m transect. An index of peat loss was calculated from the product of depth and extent of peat consumed.

The cover of living biomass estimated for shrub and non-woody ground layer vegetation was estimated visually within each 20 x 1 m transect. Given that all vegetation was consumed by the fire in December 2019 at all sampled sites, the cover estimates of live vegetation made during the surveys in March 2020 represent post-fire regrowth. Biomass samples were also collected for analysis.

Counts of seedlings and resprouting individuals of each vascular plant species were recorded in each 1 x 1 m quadrat in each transect. Species identifications were determined by botanists with extensive experience in the study area and skilled in species recognition in early post-fire regrowth. The total number of species was tallied to estimate plant species richness for each 20 m2 transect.

Analysis

All data analysis were undertaken in R statistical software (R Core Development Team 2020). Medians, quartiles, maxima and minima were calculated for the factorial combinations of landform (valley floor vs valley side) and mining treatment (mined vs unmined) for the following variables: fire severity (based on mean minimum twig diameter); peat loss index; live ground cover; and species richness. These were displayed in boxplots.

A species composition matrix was assembled by calculating the frequency of occurrence (out of 20 possible quadrats) for each species within each transect. A triangular dissimilarity matrix was calculated from this data matrix using the Bray-Curtis metric applied to all pairwise combinations of transects. A global non-metric multidimensional scaling (GNMDS) algorithm was applied to the dissimilarity matrix to generate ordination scores in two dimensions using the *Vegan* package in R. The solution was plotted in half-change units to display compositional relationships between samples across the factorial combinations of landform and mining treatment.