

# **Persistence ability of soil seed banks in burnt landscapes**

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## **Declaration**

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree or qualification.

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.



Sarah Hill

## Acknowledgements

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The major aim of the ARC Linkage project was to determine the effect of plant persistence from plot to landscape scale. This larger project has three main themes: 1) spatial analysis of fire severity, 2) the persistence ability of soil-stored seed, and 3) the persistence ability of sprouting species in relation to fire severity and intervals. The PhD project is associated with the second theme of the ARC Linkage project. The grant holders for this project are Peter Clarke, Kirsten Knox, Ross Bradstock and Tony Auld. For the purposes of this PhD project, my supervisors included Peter Clarke, Kirsten Knox and Tony Auld, with Ross Bradstock providing valuable advice when needed.

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## **Abstract**

Seed banks play a critical role in the persistence of plant populations in variable environments. In the context of fire, seed banks are a particularly important source of seed for species which are killed by fire and rely on seed stored in the soil to regenerate and persist in the landscape following such disturbance events. Fire severity can vary, depending on a number of factors including: intensity, duration of the fire, fuel loads, fuel and vegetation type, topography, climatic condition, soil texture and moisture, soil organic content, time since last fire and area burnt. Essentially fires that consume a large amount of fuel can result in greater heat penetration of the soil profile, greater soil temperatures and longer residence times during the passage of fire. This is particularly important for species with a soil-stored seed bank as heating of soil may promote or inhibit the germination of seeds in the soil and affect the regeneration of species following fires of different severities.

I examined the soil seed banks of five different plant communities in the Gibraltar Range and Washpool National Parks, New South Wales, Australia. The five communities ranged from those dominated by mesic elements with low fire frequency (Wet Sclerophyll Forest and Rainforest), to those with a strong sclerophyll component and a relatively higher expected fire frequency (Dry Sclerophyll Forest, Rocky Outcrop and Wet Heath).

This thesis consists of five data chapters, each written in the style of a scientific paper. The findings of each are summarised below:

The species composition and abundance of the soil seed banks within the five plant communities were estimated, along with the relationship between seed banks and the corresponding standing vegetation (Chapter 1). Two contrasting strategies for soil sampling, based on the size of the replicate sample, were compared to assess species richness and abundance within each plant community. Comparisons based on life form and sprouting ability of species, were also made between the soil seed bank and standing vegetation. Different sized samples did not have an effect on the number or abundance of species detected

in the soil seed bank across five plant communities nor did the size of soil samples influence the number or abundance of species with different sprouting abilities. The estimated seed density of the soil seed banks ranged from 145–834 seeds/m<sup>2</sup>, with the soil seed banks of the Rainforest and Wet Heath having the greatest density and the Dry Sclerophyll Forest having the least. Perennial species dominated the soil seed bank across all communities. Graminoids, herbs and shrubs were the most abundant and speciose life forms within the fire-prone communities (DSF, RO, WH). Within the mesic communities (WSF, RF) the most abundant and speciose life forms were herbs, shrubs and trees. Resprouting species were more abundant than obligate seeders across all communities, except the Wet Sclerophyll Forest. The standing vegetation and the soil seed bank of each community were highly dissimilar, with more species recorded in the standing vegetation than the soil seed bank of all communities, except the Rainforest. Seed storage, the transient nature of seeds, and possible lack of appropriate dormancy breaking cues were probable explanations for the absence of species from the soil seed bank.

The impact of smoke and multiple levels of heat, applied for a single duration, on species regeneration from the soil seed bank were examined for the five plant communities (Chapter 2). Soil was heated at one of four heat treatments (40, 80, 120°C, control (no heat)) for 15 minutes, with one application of smoke added after heating. Generally, smoke and heating promoted the germination of species in the more fire-prone communities (DSF, RO, WH) to a greater degree than the mesic communities (WSF, RF). Species within more fire-prone communities generally had a positive response to heat, whereas species in the more mesic, less fire-prone communities, responded negatively to heat. The legume taxa were an exception, responding the same across all communities.

I then examined the impact of burn severity on the soil seed banks of the five plant communities 6.25 years following fire (Chapter 3). Burn severity indices were developed using Landsat TM pre- and post-fire images to calculate the Normalised Burn Ratio, with

three burn classes identified for each community (low, high and an unburnt treatment). Soil seed banks in unburnt sites generally were more speciose and abundant than sites burnt during the fires of 2002, suggesting the burnt areas had not fully replenished their soil seed banks. High burn severity, generally, resulted in smaller soil seed banks than low burn severity for a number of species and plant functional groups across all communities although the extent of differences between burnt and unburnt sites was greater in magnitude. This suggests there is greater depletion of the soil seed bank in areas experiencing high severity fires, implying time taken for the replenishment of these seed banks would be longer in high compared to low severity areas.

I also compared impact of time since fire (long unburnt, 6.25 and 4.5 years following fire) on the species present in the soil seed banks of the five plant communities (Chapter 4). I examined if there was an immaturity and senescence risk to species in the soil seed bank with respect to fire frequency threshold levels. The soil seed banks in long unburnt vegetation were generally larger for a number of species and plant functional groups across all communities, indicating species were not at risk of extinction through senescence. The presence of soil seed banks in recently burnt vegetation also demonstrated that a number of species should be resilient to a risk of frequent fire of around  $<7$  years. However, many species had not replenished their seed banks after 4.5 or 6.25 years post-fire.

The potential impacts of soil temperatures in a post-fire environment were examined for legume species typical of the five plant communities studied previously (Chapter 5). Soil temperatures in a post-fire environment may be elevated due to increased solar radiation and this may influence germination of species with soil-stored seed banks. Seeds were heated at one of four temperatures (50, 60, 70°C, unheated) for three hours per day for five days to simulate soil temperatures where the canopy had been removed by fire. Simulated post-fire soil temperatures affected the germination of dormant seed by breaking seed dormancy in hard-seeded species. Small-seeded species were affected more by changes in simulated soil

temperatures than large-seeded species. Temperatures up to 70°C significantly increased the germination of species with relatively small- to medium-sized seeds, suggesting small-seeded species have lower temperature thresholds than larger-seeded species. This may indicate small-seeded species are able to germinate across a wider range of temperatures.

Consequently, post-fire germination of large-seeded species may be dependent solely upon the degree of soil heating during the passage of fire and the species may have a relatively stable residual seed bank thereafter, whereas small-seeded species may have a residual seed bank that is further reduced by the post-fire environment. This would ultimately have an impact on the persistence of the soil seed banks of species with the lowest temperature thresholds for germination in response to increasing soil temperatures in fire-prone habitats post-fire.