



Fire-climate interactions and their biodiversity implications for SW Australian shrublands

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Global importance of fire: Disturbance regime is a fundamental driver of plant community composition and structure, and of species coexistence. Fire is one of the most common causes of recurrent landscape scale disturbance, and has shaped evolution and adaptation in many taxa globally (Bond & Keeley 2005). Altered fire regimes are a significant component of global environmental change and have been implicated in species losses and invasions. Climate change is predicted to result in decreased precipitation and increased temperature across many fire-prone regions, resulting in longer fire seasons and increased fire likelihood, while reduced productivity may lead to increased fuel limitation and less fire in other situations (Moritz et al. 2012).

Fire and climate change in the mediterranean-type ecosystems: Mediterranean-type climate regions are projected to be among the most 'at risk' to the future impacts of climate change worldwide. Thomas et al. (2004) identify shrublands as the global structural vegetation type likely to lose the largest fraction of species, with the Southwest Australian Floristic Region (SWAFR) and the Cape of South Africa potentially losing the most (Malcolm et al. 2006). The mediterranean-type climate region of SWAFR covers an area of 300 000 km² and contains more than 7200 plant species, of which ~79% are endemic (Beard et al. 2000; Hopper & Gioia 2004; Mucina et al. 2014). Mean maximum temperature in the region has increased by 0.15–0.20°C per decade over the period 1900–2007, and annual rainfall has decreased by 20% since the 1970's. Climate change projections infer a continuing temperature increase and rainfall decrease, implying a climate with longer fire seasons, and more extreme fire danger days.

Fire and population dynamics: Different plant taxa, and plant functional groups, may respond to shortened disturbance intervals and their interaction with changing climate in different ways, leading to potential shifts in plant community composition, diversity, structure and function. The biota of fire prone ecosystems have key traits that enable population persistence under a given fire regime. In plants, a fundamental dichotomy exists in fire response, with some species able to resprout after fire, while others rely exclusively on seeds for regeneration. These traits result in populations that are multi-aged and long lived on the one hand, and generally single-aged and shorter lived on the other. A second factor potentially affecting plant response to fire is the mode of seed storage, either in a serotinous (canopy) or in a soil-stored seed bank (SSB). Seed banks may confer resilience in species responses to changing environmental conditions, but there could be differences in response to changing climate-fire regimes between serotinous and SSB species: While some fraction of the seed bank in SSB species may be carried over between fires, all seeds of serotinous species are released, and either germinate or perish after each fire. Populations of serotinous species, particularly prevalent in SW Australia and South Africa, may therefore be especially vulnerable to extinction under a regime of more frequent fire.

Changes in three key plant population dynamics drivers associated with changing climate and fire regimes (demography, post-fire recruitment, fire interval) will likely combine to drive perennial plant species losses and ecosystem state changes more quickly than is currently proposed based on climate envelope or fire regime shifts alone, and must be taken into account in order to more fully assess potential climate change impacts. Species in regions subject to a warming and drying climate will suffer the cumulative impacts of changes to all of these drivers, with lower post-fire population densities, slower seed bank accumulation rates and shortened fire intervals combining to exacerbate immaturity risk and drive population declines. A conceptual model is presented – the interval squeeze

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model – that provides a framework for understanding potential change impacts. Using experimental fires, and including year to year variations in rainfall, we have partly quantified the implications of interval squeeze for the biodiverse shrub species flora of SWAFR.

Outlook: Adaptive approaches to fire management to increase the probability of *in situ* persistence will be required as climate changes, and may include heightened wildfire suppression, lengthened fire intervals between prescribed fires, and targeted vegetation and climate monitoring (measuring seed stores, using seasonal rainfall projections) to better predict potential fire-climate impacts, and better meet biodiversity conservation objectives.

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Figure 1. Fire sweeping through the kwongan shrubland in SW Australia.

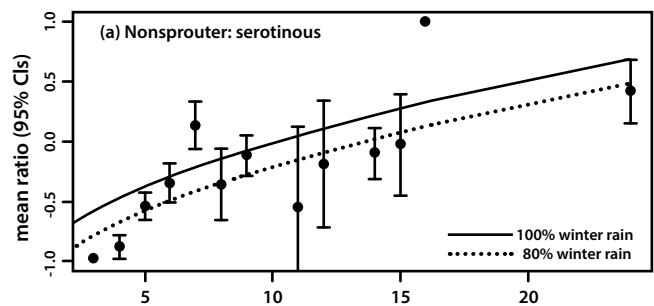


Figure 2. For species regenerating solely from seed, a 20% reduction in post-fire winter rainfall could increase the fire interval required for self-replacement by >50%.