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R.P. Thornton

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Welcome from Editor

It is my pleasure to bring to you the compiled papers from the Science Day of the AFAC and Bushfire CRC Annual Conference, held in the Sydney Convention Centre on the 1st of September 2011.

These papers were anonymously referred. I would like to express my gratitude to all the referees who agreed to take on this task diligently. I would also like to extend my gratitude to all those involved in the organising, and conducting of the Science Day.

The range of papers spans many different disciplines, and really reflects the breadth of the work being undertaken, The Science Day ran four steams covering Fire behaviour and weather; Operations; Land Management and Social Science. Not all papers presented are included in these proceedings as some authors opted to not supply full papers.

The full presentations from the Science Day and the posters from the Bushfire CRC are available on the Bushfire CRC website www.bushfirecrc.com.

Richard Thornton

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Human fire maintains a balance of nature.

Vic Jurskis
Forests NSW, 6 Cocks Lane, Eden NSW 2551 Australia

Abstract

A perception of conflict between conservation of biodiversity and burning for socioeconomic protection persists in Australia. Numerous studies of 'impacts of burning' have concluded that burning depletes nutrients, simplifies vegetation structure by reducing woody vegetation and fallen timber, and threatens biodiversity. However ecological history shows that burning can maintain a dynamic balance in eucalypt ecosystems whereas nutrients, woody vegetation and fallen timber accumulate in the absence of fire, impairing their health, resilience, diversity and safety. Some recent studies of fire and nutrient cycling have elucidated the underlying processes and provided insights into the intervals between fires that can maintain health, resilience and diversity. Human fire is part of the 'balance of nature' in eucalypt ecosystems.

Introduction

Human fires have had a pivotal role in Australia's ecological history (e.g. Pyne 1991; Bowman 2003; Gammage 2011; Jurskis 2011). About the time Aboriginal people occupied Australia, climate was relatively stable but there was a peak in charcoal production and mesic vegetation retreated whilst eucalypts and grasses became dominant indicating that human fires were primarily driving vegetation change (Kershaw *et al.* 2002). Consequently browsing megafauna with specialized diets gave way to less specialized grazers (Miller *et al.* 2005; Prideaux *et al.* 2007). Subsequently charcoal production or biomass burning declined and then remained at relatively low levels for about 20 ka until the time of European settlement (Mooney *et al.* 2010). Woody thickening, loss of ground layers and associated fauna, pest outbreaks, eucalypt decline and extensive conflagrations occurred when Aboriginal fire management was displaced by European settlers (Mitchell 1848; Curr 1883; Howitt 1891). Charcoal production peaked once more, then declined from the mid 20th Century as broadscale prescribed burning including aerial ignition reduced the frequency and extent of wildfires (Jurskis *et al.* 2003; Boer *et al.* 2009; Mooney *et al.* 2010). There has been a resurgence in eucalypt decline, extensive wildfires and loss of species over recent decades with expansion of unmanaged conservation reserves and reduced prescribed burning (Jurskis 2005, 2011; Adams and Attiwill 2011).

The proposition that prescribed burning threatens biodiversity in Australia (e.g. Morrison *et al*. 1996; Bradstock *et al*. 1998; Henderson and Keith 2002) ignores this ecological history and views burning as a disturbance that impacts our environment rather than an essential part of the natural balance (Jurskis *et al*. 2003; Attiwill and Adams 2008; Adams and Attiwill 2011; Jurskis 2011; Jurskis *et al*. 2011). The scene was set in 1976 when the international Scientific Committee on Problems of the Environment initiated a project on 'The Effects of Fire on Ecological Systems'. Under this project Gill (1981) popularised the notion in Australia that the response of non-sprouting plant species to fire was either reproduction from seed or local extinction. Since then we have seen thirty years of ecological research focused on life cycle analyses of obligate seeders in an effort to identify critical thresholds for prescribed fire intervals to maintain biodiversity (e.g. Keith *et al*. 2002). This work has been based on assumptions that prescribed fires kill most/all obligate seeders within their boundaries, that fire sensitive plants grow naturally on fire prone sites and that sites which have had little recent human activity reflect natural (pre-European) conditions (e.g. Morrison *et al*. 1996; Bradstock *et al*. 1998; Henderson and Keith 2002).

The first assumption has been based largely on observations of plants' responses to wildfire and has been contradicted by studies of prescribed burning (e.g. Jurskis *et al.* 2003; Penman *et al*. 2008). The second and third assumptions fail to recognize that fire sensitive plants were mostly confined to refugia such as rock outcrops, swamps and deep, dark gullies by Aboriginal burning and increased greatly in number and extent after Aboriginal burning was disrupted (e.g. Pyne 1991; Jurskis 2002, 2009, 2011; Jurskis *et al*. 2003; Gammage 2011). For example, Morrison *et al*. (1996) compared floristic composition against fire intervals in woodlands and shrublands near Sydney that had been burnt by a megafire and several other wildfires and prescribed fires during a quarter of a century. They assumed that European settlement did not change the fire regimes and implicitly, the vegetation.

However the historical record (e.g. Mitchell 1839, 1848) shows that European settlement had profound impacts on fire regimes and vegetation in this area and the floristic homogeneity across vegetation formations (Morrison *et al*. 1996) is a consequence of post - European disruption of Aboriginal burning and imposition of a regime of less frequent and more severe fires (Jurskis *et al*. 2003; Gammage 2011; Jurskis 2011). Morrison *et al*. (1996) found that short (< 7 years) intervals between fires reduced the abundance of five very common shrubs that currently dominate vegetation on Hawkesbury sandstone and increased the abundance of two less common shrubs. The very common shrubs were more abundant on sites with short fire intervals than were the uncommon shrubs on sites with long fire intervals and one of the uncommon shrubs was absent from sites with long fire intervals (Morrison *et al*. 1996 Table 2). Thus Morrison's *et al*. (1996) conclusion that biodiversity will be lost if there are short intervals between prescribed fires is at odds with their data.

Studies of frequent prescribed burning in New South Wales State Forests have confirmed that most obligate seeders are promoted by burning whilst a few common shrubs are disadvantaged (Jurskis *et al*. 2003; Penman *et al*. 2008). Species richness starts to decline within a short time after fire while shrubs are increasing in numbers and density (Penman *et al*. 2008, 2009). This points to competition rather than burning as the cause of species loss and several studies have shown that a few common 'fire sensitive' shrubs proliferate at the expense of many smaller species in the absence of fire and/or grazing (e.g. Jurskis *et al*. 2003; Penman *et al.* 2008, 2009; Price and Morgan 2009; Jurskis 2011). This contributes to chronic tree decline, fire hazard problems and loss of rare biota (Jurskis 2011). Instead of basing prescribed fire intervals on disproven theories we should be looking at the timing of the processes of competition, nutrient cycling and fuel accumulation that cause these problems.

Ecological processes

In dry forests at Eden, groundcover species richness declined within 3 or 4 years of fire (Penman *et al*. 2008 Fig. 4c; Penman *et al*. 2009 Fig. 1a) and continued to decline by 6 species over 20 years (Penman *et al*. 2009 Fig. 1a). Shrub species richness increased by 2 species over 15 years after fire (Penman *et al*. 2009 Fig. 1a), whilst shrub density increased by 1500 stems per hectare over 20 years after fire (Penman *et al*. 2009 Fig. 2). In the same forests, substantial accumulation of soil N occurs after 10 years without fire and C:N is reduced causing increasing acidity and nutrient imbalances that are harmful to eucalypts (Turner *et al*. 2008). These changes are exacerbated by microclimatic changes associated with shrub development such as increased shading and topsoil moisture (Jurskis *et al*. 2011) and by proliferation of N-fixing shrubs such as acacias and casuarinas (Turner *et al*. 2008). Fire ecologists typically report that burning depletes soil N (e.g. Christie and York 2009) because they compare levels in frequently burnt areas against long unburnt 'controls' where N has accumulated over several decades (Turner *et al*. 2008; Jurskis *et al*. 2011). Based on rates of N accumulation in the absence of fire and N removal by prescribed burning, Turner *et al*. (2008) suggested that an interval of about 5 years between fires would maintain dynamically stable nutrient cycling processes. This is similar to the interval that would maintain competitive interactions supporting maximum plant diversity and minimum shrub cover according to the data of Penman *et al*. (2008, 2009).

In the study reported by Penman *et al*. (2008) frequent burning was ineffective after 1994, cumulatively affecting only 30% of the treatment area compared to 130% in the period to 1994 (Penman *et al*. 2007 Fig. 2(b)). Species richness declined at a rate inversely proportional to the area burnt (Penman *et al*. 2008 Fig 4(c)) indicating that the declines were occurring in unburnt areas (Fig. 1). Declining health of eucalypts as indicated by rates of infection by mistletoes (Jurskis 2005) showed a similar pattern. Between 1990 and 2004 mistletoes doubled in the frequent burning treatment while they quadrupled in the other treatments (Jurskis *et al*. 2005) suggesting that eucalypt health declined in the frequent burning treatment after 1994 when burning was ineffective. Assuming that mistletoe numbers were stable when frequent burning was applied effectively, they increased at a similar rate in all treatments after 1994 (Fig. 2).

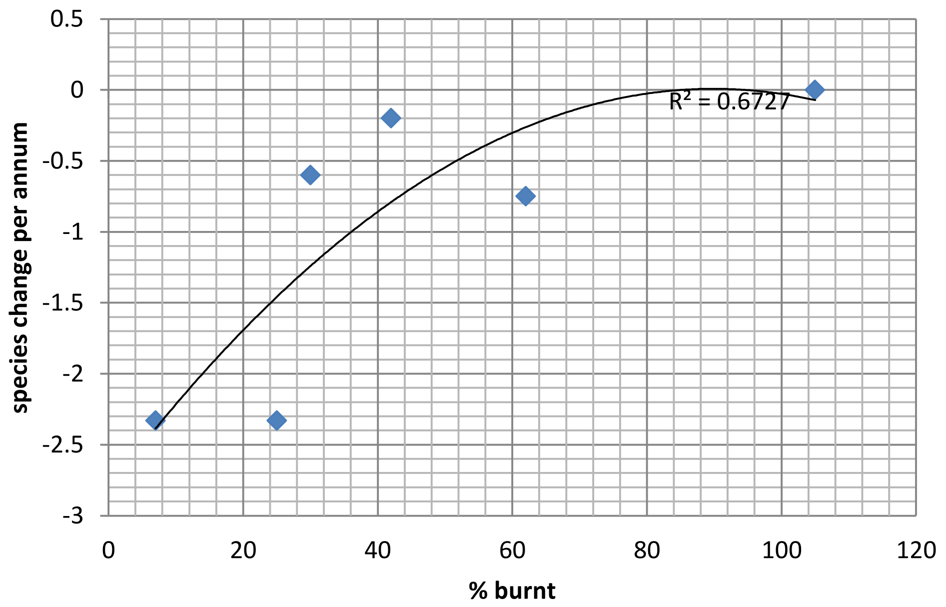

Figure 1 Rate of species loss according to area burnt during the corresponding period

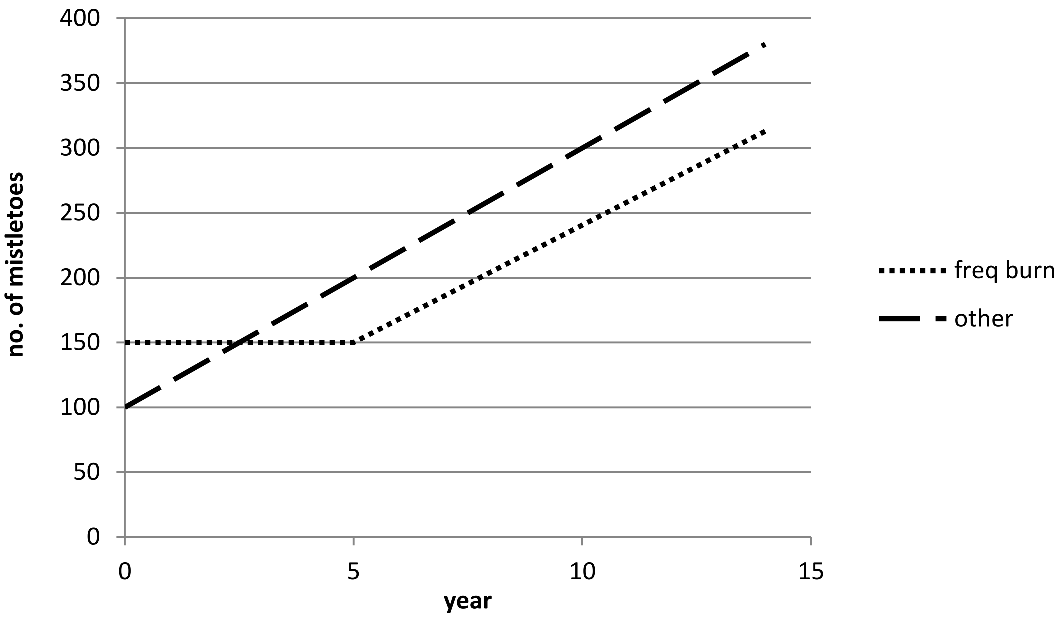

Figure 2 Increasing mean count of mistletoes by treatment between 1990 and 2004. Count for year 5, frequent burn treatment is a dummy variable.

Irruptions of bellbirds are another indicator of declining health in eucalypts because they follow irruptions of psyllids stimulated by enhanced nutrient value of leaves on declining eucalypts (Jurskis 2005). Increasing populations of bellbirds were closely correlated with lack of fire in the Eden burning study (Fig.3).

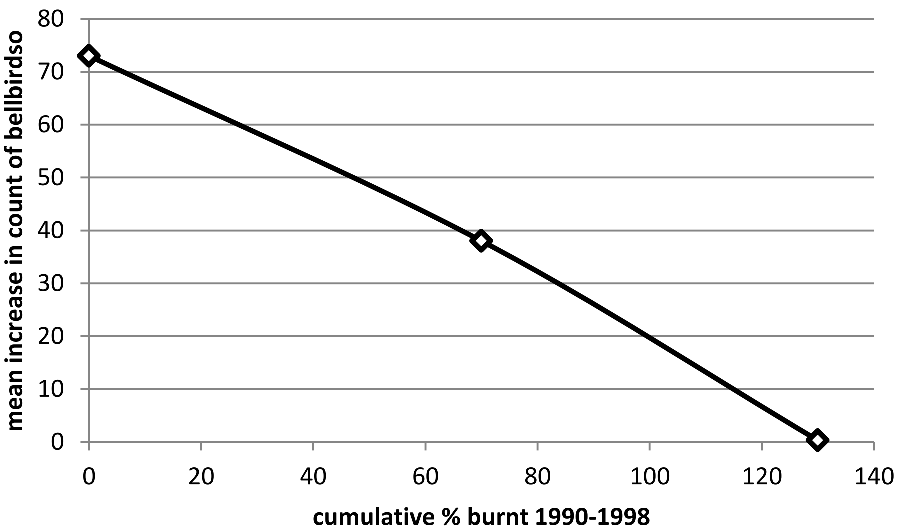

Fig. 3 Increase in bellbirds according to cumulative percent of area burnt 1990 – 1998.

Accumulation of litter, fallen timber, shrubs and fibrous bark on eucalypts reduces fire safety by increasing the quantity and three-dimensional continuity of fuels. Shading, reduced air circulation and increased topsoil moisture exacerbate the problems because the accumulating fuels are not flammable in temperate conditions but explosively flammable in severe conditions (Jurskis *et al*. 2003). However burning studies often measure a relatively small proportion of the fuels available to high intensity fires in severe conditions. For example, Birk and Bridges (1989) measured fuels up to 25 mm diameter and up to 0.9 m above the mineral soil, described as fine fuels, in dry blackbutt (*Eucalyptus pilularis*) forest on New South Wales' north coast. These fuels accumulated to pre-burn levels within 4 years. However Birk and Bridges (1989) noted that fire hazard was reduced because frequent burning restored a grassy understorey at the expense of woody shrubs such as Lantana or Allocasuarina and that this was not well reflected in the fine fuel measurements. In contrast, Penman and York (2010) did not recognize that much fuel was not measured (i.e. fuel > 25mm diameter, fuel > 0.9 m above the mineral soil, fibrous bark on trees such as blackbutt) and thus concluded that burning did not reduce medium term fuel loads. They also did not recognize the natural diversity of groundlayers in dry and moist eucalypt forests (> 70% of total species richness, Penman *et al*. 2008 Figs. 2, 4) and suggested that frequent burning would be environmentally harmful by 'reducing', i.e. controlling, shrubs (Jurskis *et al*. 2011).

The efficacy and longevity of fuel reduction by burning has been demonstrated empirically in the dry eucalypt forests of southwestern Australia. Boer *et al*. (2009) found that burning reduced the extent and incidence of wildfires over half a century and that the effect lasted for 6 years after burning. Since the three aspects of competition, vegetation/fuel mass/structure and nutrient cycling are inextricably linked, it is not surprising that they point to similar fire intervals (3-6 years) to maintain biodiversity, health and fire safety of dry eucalypt forests. This is consistent with estimates of pre-European fire regimes derived from a combination of dendrochronology, sedimentary charcoal, grasstree records and historical accounts (e.g. Mitchell 1848; Curr 1883; Howitt 1891; Burrows *et al*. 1995; Ward *et al*. 2001; Abbott 2003; Hassell and Dodson 2003).

In contrast 'acceptable' fire intervals according to theoretical life cycle analyses are from 7 to 30 years and there are calls for more detailed study of the requirements of species associated with long unburnt areas (e.g. Penman *et al*. 2009). Thus there is a failure to recognize that fire sensitive plants are naturally associated with physically protected habitats and that this protection is reinforced by frequent low intensity burning in the landscape (e.g. Bowman 2003; Jurskis *et al*. 2003; Burrows 2005). In the absence of frequent burning, the majority of fire refugia throughout whole regions can be reset to a young fire age by megafires as happened in wet sclerophyll ash forests in Victoria following megafires in 1939 and on three occasions between 2002 and 2009 (Adams and Attiwill 2011). Similarly all the granite outcrops formerly providing fire refuge to rare species in southwestern Australia were burnt throughout 18,000 hectares by a single high intensity fire in 2003 after 20 years of exclusion of fire from a National Park (Burrows 2005).

Conclusion

Eucalypt forests are fire dependent ecosystems that were shaped by human burning over about 50 ka (Pyne 1991; Bowman 2003). Loss of species (e.g. Bowman 2003; Penman *et al*. 2008; Jurskis 2011), chronic decline of eucalypts (Jurskis 2005; Close *et al*. 2009, 2011; Jurskis *et al*. 2011) and megafires (Jurskis *et al*. 2003; Adams and Attiwill 2011) can occur with environmental changes in the absence of frequent burning. Human fire is essential to maintain diversity, resilience and fire safety in these forests.

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