Meetings

Fire futures for a megadiverse continent

Bushfires, biodiversity and climate change working group and workshop, Hobart, Australia, May 2012

Climate change has the capacity to fundamentally alter global fire regimes. The Australian continent is megadiverse with respect to both biodiversity, and fire regimes. It is an ideal 'laboratory' within which interactions between climate change, fire regimes, ecosystems and people can be examined. Leading fire researchers and senior fire and biodiversity managers met at a recent national workshop in Hobart, Australia, to discuss these complex interactions, and how fire management may adapt to the challenges of the coming century. Regional responses of fire regimes to climate change may vary. Fire activity may increase due to rising temperatures and decreasing humidity. Alternatively, fire activity may decrease if ecosystem productivity decreases due to declining rainfall. Climate change will also interact with other drivers, such as the spread of alien species, to alter fire regimes. Such changes in fire regimes may lead to gradual changes in ecosystem composition and structure, or the changes may be rapid and transformational. How fire is managed under climate change scenarios will also have effects on biodiversity. Targeted ecosystem monitoring in the field and enhanced national fire regime mapping capacity are both critical to predicting and managing ecosystem changes resulting from climate change-induced changes to fire regimes.

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Fire regimes and global change

Fire is integral to the Earth system (Bowman *et al.*, 2009). Fire regimes are an emergent property of a complex set of biophysical drivers and feedbacks (Marlon *et al.*, 2008; Parisien & Moritz, 2009; Bradstock, 2010). Climate change, through its effects on fire weather and fuels, and in conjunction with other global changes, therefore has the capacity to fundamentally alter fire regimes (*sensu* Bradstock *et al.*, 2012b). However, how fire regimes will respond to climate change, and what consequences will ensue for landscapes and people, is uncertain. Potentially, climate change may cause increases in fire activity and area burnt and decreases in intervals between fires (Turetsky *et al.*, 2011; Westerling *et al.*, 2011). Alternatively, fire activity may decrease if ecosystem productivity decreases due to declining moisture availability. Interactions between climate change and fire regimes, combined with other global drivers of environmental change are most certainly going to have substantial effects on biodiversity. The risk to people and property of elevated fire activity, especially at the interface between urban areas and flammable ecosystems, is of global concern (Gill & Stephens, 2009).

Current fire management incorporates a very diverse range of objectives (e.g. protection of human life and well-being, conservation of biodiversity, water and catchment management, carbon dynamics) that do not always harmonize. A key approach to protecting people and their assets is fire suppression and fuel management (Gill & Stephens, 2009). Biodiversity conservation emphasizes differing aspects of fire regimes (fire intensity and fire frequency; Bradstock *et al.*, 2012b) that are all potentially sensitive to substantial climate change, but are likely to be biome-specific (Bradstock, 2010). Fire management in coming decades will also be increasingly used to optimize carbon benefits, through reduced emissions of greenhouse gases (GHG) and enhanced carbon sequestration (Hurteau *et al.*, 2008; Campbell *et al.*, 2011; Bradstock *et al.*, 2012a; Williams *et al.*, 2012). Finally, reducing the effects of smoke on human health, whether from wildfire or from prescribed fire, has become an important management objective (Johnston *et al.*, 2011).

Questions regarding climate change and fire are of immediate relevance to scientists, fire managers, policy-makers and the general public, across many sectors of society. However, attempts to pose answers to questions regarding the direction and rate of potential change, and the potential consequences of change for people and landscapes, are thwarted by the complexity of mechanisms and interactions among key processes that affect fire. There are many conundrums, with global implications.

Recently, a meeting in Australia entitled 'Bushfires, biodiversity and climate change' was convened to explore these complex issues. The 21 participants were drawn from a number of research and management agencies. The meeting was supported by the National Climate Change Adaptation Research Facility, NCCARF; http://www.nccarf.edu.au/). The principal task was to explore the intersection of the conservation of biodiversity and the management of fire in the face of climate change, and to provide guidance to fire and biodiversity managers on practical pathways to adapt fire and biodiversity management to the changing, but uncertain, circumstances of the 21st century. The workshop brought together leading fire ecologists and managers to address this problem.

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Australia as a climate change and fire 'laboratory'

Australia is an ideal 'laboratory', within which to scrutinize these ideas. It is a megadiverse continent, with respect to both biodiversity, and fire regimes (Bradstock *et al.*, 2012b). Australia has an active program of fire regime mapping, which allows fire regime components, and their sensitivity to climate and climate change, to be analyzed at broad spatial and temporal scales. It has seen high levels of fire activity in recent years that have had substantial impacts on human life, well-being and property. There is substantial variation in fire activity with major differences in frequency, intensity and seasonality of fires between the temperate south, the arid interior, and the tropical north (Bradstock *et al.*, 2012b). In Australia, the imperatives to protect people and property and biodiversity have long been co-priorities in fire management (Bradstock *et al.*, 2012b). Crucially, there is substantial political and public engagement with the question of fire management, now and in the future, as a result of recent major fires.

Under all climate change scenarios and global change models much of Australia is projected to become warmer in the coming decades resulting in more severe fire weather (Clarke *et al.*, 2012). The impact of climate change on fuels is more difficult to predict, but may well result in declining fuels, under the drying scenarios for the southern, most densely populated part of the continent (Matthews *et al.*, 2012). The management of Australian landscapes for future fire regimes, therefore, raises profound global questions regarding the nexus between people, landscapes and fire: How much of a landscape should be treated with prescribed fire? How might planning respond to elevated fire risk? Will management to reduce risk to people inevitably have biodiversity costs? The workshop therefore posed the question: In the face of uncertainty, what do we need to know and do to manage fire regimes in a megadiverse continent so that we sustain our people, and our globally important biodiversity?

Interactions between climate change, fire regimes and ecosystems

Dick Williams (CSIRO, Darwin, Australia) introduced the meeting by summarizing recent work on climate change, fire regimes and biodiversity supported by NCCARF, the Australian Centre for Ecological Analysis and Synthesis (ACEAS), the Commonwealth Department of Climate Change and Energy Efficiency and the CSIRO Climate Adaptation Flagship. This work has examined interactions between climate change and fire weather, fuels and risk to landscape assets (Williams *et al.*, 2009, 2011). Mike Grose (CSIRO, Melbourne, Australia) and Rebecca Harris (University of Tasmania, Hobart, Australia) briefly reported on climate change scenarios for Australia. Australia's bio- and pyro-diversity reflects a long co-evolutionary relationship. This has resulted in a large diversity of fire regimes across the continent, which varies in seasonality, intensity and frequency. Brett Murphy (South Dakota State University, Brookings, USA), Matthias Boer (University of Western Sydney, Sydney, Australia) and Owen Price (University of Wollongong, Australia) presented recent work supported by ACEAS (Murphy *et al.*, 2011) on quantifying and mapping the fire regime syndromes of Australia, using standard meteorological and vegetation map data. They termed these syndromes of fire regimes 'fire countries'. Overlaid on this is a very long history of anthropogenic fire use, in virtually all major biomes. This has also resulted in even further co-evolutionary adjustments, as pointed out by David Bowman (University of Tasmania, Hobart, Australia). These evolutionary processes and outcomes have been further affected by European land use over the past 200 yr.

Current management of fire is complex, and contested, and fire management at landscape scales is being made more complicated by climate change. For example, Neal Enright (Murdoch University, Perth, Australia) and Lachie McCaw (WA Department of Environment and Conservation, Manjimup, Australia) pointed out that the shrubland ecosystem of southwest Western Australia, a global biodiversity hotspot, is being affected by drought to the extent that fuel availability to burn (connectivity and moisture) has increased, leading to potentially more frequent fire, even though long-term drought may lead to a decline in fuel mass (Matthews *et al.*, 2012). However, the same climate change circumstances of warming and drying means that increased time is required for biota such as obligate seeders to reach critical life history stages. Thus climate change is causing maturation times or juvenile periods to lengthen, while concurrently the interval between fires may be decreasing, a phenomenon aptly termed 'interval squeeze' (Bradstock *et al.*, 2012b). Conversely, Dick Williams (CSIRO Darwin, Australia) provided an example where observed climate warming and drying in the Australian alpine zone is potentially being accommodated by the broad plant biota, by compensatory effects (e.g. Hoffmann *et al.*, 2010) which off-set the effects of rising temperatures. Taking a South African perspective, William Bond (University of Cape Town, South Africa) argued that a fundamental driver of fire regime change is CO_2 enrichment (Bond & Midgley, 2012) which changes the competitive balance between woody sprouters and seeders. These contrasting responses accord with the framework proposed by Ross Bradstock (University of Wollongong, Australia) and Geoff Cary (Australian National University, Canberra, Australia) that changes could be incremental, or transformational. In either case, novel fire regimes may ensue (e.g. Fig. 1).

The diversity of Australia's fire regimes, the strongly contrasting climatic influences, projected climates, and plausible CO_2 effects, imply a diversity of possible responses to climate change. This, in turn, underscores the need for adaptive strategies and capacities to be proposed and evaluated. This may be business as usual in some cases, but will also entail novel solutions for the novel problems and ecosystems that may arise under climate change. For instance, controlling the spread of aggressive grasses that can transform fire regimes requires the treatment of satellite outbreaks of the grasses as a high priority (Suzanne Prober, CSIRO, Perth, Australia). In some protected areas in Queensland, 'conservation grazing' using domestic cattle is being trialed in areas already affected by invasive grasses (Rhonda Melzer, Queensland National Parks and Wildlife Service, Rockhampton, Queensland). David Bowman suggested some extremely novel, some might say drastic, approaches to contain some aggressive exotic grass such as intentionally over-

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Fig. 1 Australian tropical savanna invaded by the non-native tall grass *Andropogon gayanus* (gamba grass). Grass fuel loads are substantially higher in invaded sites, and the more intense fires that ensue can transfom savanna composition and structure (Setterfield *et al.*, 2010). Photograph by Samantha Setterfield.

grazing rangelands to induce woody dominance, or using exotic mega fauna such as white rhino or elephants to break run-away grass-fire cycles (Bowman, 2012).

How the Australian fire countries will react to climate change (including elevated CO_2) and the flow-on effects to ecosystems will also depend on interactions between climate change and stressors that can be described as wildcards or 'X-factors'. These may cause changes outside the realm of scientific knowledge; such changes may provide insights into the nature of the evolutionary coupling of fire and grass and herbivore interactions. For example, William Bond noted that the capacity of invasive soft perennial grasses, (e.g. the African grass *Cenchrus ciliaris*) to overcome resource limitations (low nutrients, episodic rain) and thereby out-compete the native *Triodia* grasses, cannot be explained by current ecological theory.

Given these plausible, but uncertain outcomes, a key recommendation of the workshop was to increase investment in targeted ecosystem monitoring in the field, as opposed to building models that may not be able to predict ecosystem changes resulting from climate change and interacting 'X-factors'. Two ecological monitoring approaches were emphasized – surveillance monitoring to chart trajectories and detect change, and evaluation monitoring to test the efficacy of intervention. For example, in Kakadu National Park surveillance monitoring has been able to show (1) change in season of burning, as per management objectives and (2) a decline in critical biota (e.g. small mammals; Woinarski *et al.*, 2011) but is unable to explain if fire is driving the mammal declines. This can only be achieved by targeted and well-designed experiments. Of central importance underpinning both monitoring approaches is the need to develop a nationally consistent fire regime-mapping program. Such a resource is critical for both basic science and management (Mark Cladhill Tasmanian Fire Service, Hobart, Tasmania; Adrian Pyrke; Tasmania Parks and Wildlife Service, Hobart, Tasmania; Liz Tasker, New South Wales Office of The Environment and Heritage, Sydney, Australia; Jill Read, Parks Victoria, Halls Gap, Australia; Rhonda Melzer).

Protecting people and biodiversity in a flammable landscape

Recently, the bushfires of 2009 in the State of Victoria burnt 400 000 hectares in several days, killed 173 people and destroyed over 2000 properties (Gibbons *et al.*, 2012). The fires themselves may not necessarily be unprecedented (there have been larger fires) but they may be a harbinger of future fire activity. The response of Governments to these fires has been unprecedented. They precipitated a Royal Commission (Teague *et al.*, 2010) which recommended treating 5% of Victorian public land by prescribed burning, as a means of managing fire risk. This is very controversial, both in terms of risk mitigation, monetary cost and effect on biodiversity. As was pointed out at the Workshop, the '5% solution' is being exported to some other States in Australia, but not necessarily with due acknowledgment of fundamental differences in biogeographic context and fire regimes. Alan York (University of Melbourne, Creswick, Australia) provided an example from the Otway region in southwest Victoria. Modeled projections indicate that at a treatment rate of 5% per annum, some parts of the landscape will be pushed outside tolerable fire intervals (TFIs) currently used for conservation management. The longer-term effects of this are not known. Although a detailed program of monitoring was also recommended by the Bushfire Royal Commission (Teague *et al.*, 2010), and some sites established, the magnitude and extent of current monitoring (as recommended by the Royal Commissions) needs to be substantially increased to effectively detect change.

The diversity of fire regimes in Australian 'fire countries' demands regionally tailored solutions. This will involve examination of the trade-offs that arise when different assets and values in the landscape require contrasting, and in some case mutually incompatible, fire management interventions to sustain them. For different biomes the amount of risk mitigation for a given level of effort, and the associated environmental effects required evaluation, and, as noted earlier, these analyses hinge on monitoring. An example of effective decision support framework was presented by Craig James (CSIRO, Canberra, Australia). Jess O'Brien (University of Freiburg, Germany) stressed that communicating this complexity regarding climate change, fire regimes, people and landscapes to the people of Australia is essential. Brett Murphy and Owen Price concluded with an example from remote Indigenous lands in northern Australia, where tailoring fire management on the basis of an emissions reduction benefit provides potential sequestration, biodiversity and livelihoods benefits (see Russell-Smith *et al.*, 2009). A key message from such multi-partner land management programs is that efficiencies, and potential win-win solutions, are likely to result where multiple co-benefits of management can be articulated and delivered.

Acknowledgements

The authors thank the National Climate Change Adaptation Research Facility and the CSIRO Climate Adaptation Flagship for supporting the workshop.

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Key words: Australia, biodiversity, climate change, ecological monitoring, fire regimes, fuels, invasive species.

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