

Fire, landscape and health

Fay Johnston, Public Health Physician, Menzies School of Health Research and Centre for Remote Health, **David Bowman**, Director ARC Key Centre for Tropical Wildlife Management, Charles Darwin University

ABSTRACT

Functioning natural landscapes are essential for human survival. However, understanding the complex relationships between human health and landscapes beyond the immediate requirements for clean water, food and shelter (classical 'environmental health'), has only recently taken root in health and ecological research programs. This emerging field is becoming known as 'ecohealth'. Here we illustrate the opportunities, and challenges to such research collaborations using the example of landscape fire.

Australia is the quintessentially flammable continent. From coastal, tropical, arid and temperate zones fire plays a fundamental role in the functioning of our ecosystems. Following the human colonisation of Australia during the last ice age a balance between fire, land and hunter-gatherers was forged and subsequently maintained for millennia. The breaking of this relationship by pyrophobic European settlers caused dramatic changes to the health of both 'country' and the Aborigines who were extirpated of their ancestral lands or denied the right to burn the bush.

Since European colonisation the relationship between fire and people in Australia has increased in complexity. Multiple dilemmas confront those who manage our highly flammable bush and it is essential for current land managers to understand the extraordinary long evolutionary and cultural history of landscape burning. Uncontrolled severe fires destroy property, adversely affect mental and physical health and degrade amenity values. In addition the smoke from bushfires causes severe air pollution that increases cardiovascular and respiratory illnesses in exposed communities. These risks must be balanced against the environmental and social impacts of interventions to reduce fire hazards such as landscape clearing and intentional burning. 'Controlled fires' cause frequent episodes of lower levels of air pollution and the public health impact of this pattern of exposure compared with episodic severe pollution is unclear. Further, fuel reduction alone cannot provide a simple answer to preventing severe fires. Global environmental change such as frequent droughts and increased production of fuels due to the CO₂ fertiliser effect may be important contributors to the increased frequency of severe vegetation fires that has been observed around the world.

Clearly the nexus between human and landscape health is complex. Historically there has been intellectual isolation between landscape and health scientists even though these fields are fundamentally related. Nonetheless, as human adapt to the challenges of global environmental change and the associated changing patterns of human mortality and morbidity, the field of 'Ecohealth' will become increasingly important.

INTRODUCTION

Every summer in Australia we go to considerable lengths to avoid bushfires. We grew up with stories of disasters and learnt very early to fear and respect fire. We have forecasts of fire risk and legislation against deliberate use of fire on certain days or throughout entire seasons.

Throughout the country we have internationally respected fire fighting services, and we are committing more and more resources to bushfire control strategies and research. So are we winning the battle? Are fire disasters in Australia becoming less frequent and less severe? And are we coping better when disasters occur? It's hard to be sure about any of these – the fires in South Australia earlier this year claimed nine lives – earning the title of the most deadly fires in two decades. What caused them to get out of control so quickly? Had the bush been mismanaged? Had excess fuel been allowed to build up? Were there insufficient firebreaks? Or was this a consequence of the changing global climate causing an increase in the frequency of extreme fire danger days?

Landscape fires make a fascinating case study of the nexus between humans and landscapes, that goes far beyond the simplistic notion of land as a provider of food water and shelter and beyond the identification, description and quantification of environment hazards. For example, to understand how to live in a “land of fire” we need to understand the interactions between climate, fire and our flora and fauna over vast time scales and how these have interacted with human inhabitants over time. We also need to understand how our management and intervention strategies affect our environment, economy and community. Such transdisciplinary research clearly falls into the domain of the new and growing field of Ecohealth (see www.ecohealth.net) which recognises the inherent interdependence of the health of humans with their social and economic environments, wildlife and ecosystems^{1 2}. Here we examine bushfires from all of these perspectives. First we briefly sketch why Australia is so flammable and why total fire suppression is an impossible and risky dream. Then we will discuss current issues surrounding bushfire disasters and management and finally we reflect on transdisciplinary work for practitioner and researchers alike.

The ecological context of bushfires

In his description of three great ages of fire in Australia: “wild, tamed and feral” Bowman³ has provided a useful framework for understanding the ecological and evolutionary context of bushfires.

The wild age

The period of wild fires refers to the pre-human period when lightning started massive wild fires and enabled fire-adapted species to eventually subordinate the Gondwanan rainforests that originally clothed the entire continent. As Australia broke from the super-continent Gondwana and drifted northwards the subtropical high-pressure system intensified and also moved northward triggering the progressive aridification of the continent from the south to the north⁴. Sometime after the mid-Tertiary (the age of the mammals that followed the demise of the dinosaurs), a monsoonal climate developed in northern Australia⁵ in which lightning storms produced fires regularly at the end of each rain free dry season. Occasional storms would have penetrated deep into the continental interior starting fires at the beginning of the drought-prone summer months. Such reliable natural ignitions provided an extraordinary evolutionary theatre allowing for vegetation to adapt to fire rendering Australia the most fire prone continent on Earth. In this way a ‘coarse-scale’ mosaic of large tracts of burnt vegetation in different stages of recovery was created. (Fig. 1a)

The tamed age

This age refers to the period during which wildfires were tamed by humans and generations of Aboriginal people created a cultural landscape through their skilful use of fire. Sometime towards the end of the ice-age, or about 40–60 000 years ago, humans arrived in Australia. There is little doubt that they brought the technological means to make fire. Over time the colonists gradually ‘tamed’ wildfire as they used fires to hunt game, a practice often described

as 'fire-stick farming'. The core feature this was the reduction in the spatial extent of landscape fires (Fig. 1b). These changes in fire regimes modified habitats in a way that disadvantaged some species such as *Genyornys newtoni*, the extinct, leaf eating giant bird that required long-unburnt habitats⁶, but supported others such as kangaroos that were better adapted to burnt landscapes. Many smaller animal species, adapted to living at the edges of burnt areas, became dependent upon the fine-grained mosaic created by Aboriginal patterns of burning and the more recent cessation of Aboriginal fire management has been identified as an important cause of the extinction of smaller mammals and some bird species in the Australia's interior and monsoon tropics.^{7,8}

The feral age

The age of feral fire is the age of European colonisation, 1788 to the present. The new colonists clearly could not have understood the fundamental importance of fire in Australia's evolutionary and cultural history. While early navigators observed fires and commented upon these as evidence of humanity the underlying reasons the fires were lit were often misunderstood. As Charles Darwin wrote on 19 January 1836.

In the whole country I scarcely saw a place, without the marks of fire; whether these may be more or less recent, whether the stumps are more or less black, is the greatest change, which breaks the universal monotony that wearies the eyes of a traveller.

The Europeans brought very different knowledge, experience and attitudes towards fire. As Dame Mary Gilmore noted in the 19th Century Aboriginal people managed fires calmly and with familiarity while the whites "expended the energy of panic"⁹. While it is true that in some cases squatters, shepherds and cattlemen adopted Aboriginal burning practices, this technological transfer ceased with the more intensive husbandry of stock that required investment in infrastructure such as fencing¹⁰. Little thought was given to the consequences of disrupting the system of fire management that had moulded the Australian landscapes for thousands of years. Aboriginal people were driven from their lands¹¹ and every effort was made to suppress fires. Fuel loads built up and frequent small fires were replaced by spatially widespread and intense fires. (Fig. 1c) Fire is, of course, only one part of this story. To this day we are only beginning coming to terms with the many consequences of this cataclysmic disruption for land, ecosystems and people.

Current contexts: coping with 'feral' fires

This transition from tame to feral fire can be considered the root of the current fire management problem. The challenge for modern day land managers is to once again tame fire to both reduce the loss of life and property but also to conserve biodiversity. However, deliberate use of fire now represents a tremendous challenge because of the construction of infrastructure and habitations established in bushland, capricious social values about landscape fire and the very limited practical opportunities to undertake burning. So how much of a problem are bushfires today and what are the practical options for addressing these?

The social, economic and public health impact of bushfires

In the past 40 years major Australian bushfires have been estimated to have caused losses to the order of \$2.5 billion (Fig 2). This corresponds to an average of about 10 per cent of the cost of all major natural disasters, including droughts, floods, cyclones and earthquakes over the same period¹². These estimates neither include the costs of fighting fires nor the impact of the lives of human casualties. Bushfires over the same period have directly claimed 259 lives, the greatest loss of life associated with any category of natural disaster¹². Major bushfires are also well recognised for their long term health impacts on those directly affected. In South Australia 1526 survivors of the Ash Wednesday fires of 1983 were surveyed one year after the event. A

significant increase in stress-related conditions, including hypertension, gastrointestinal disorders, diabetes, and mental illness compared with the general population was recorded.¹³ Forty-two percent of respondents met the criteria for a psychiatric diagnosis particularly anxiety, depression and post traumatic stress disorder, a much greater proportion than in communities that have not experienced a natural disaster. Another follow up twenty months after the fires demonstrated lasting psychiatric morbidity from this event.¹⁴

In addition to these direct effects, major bushfires usually push particulate air pollution concentrations well beyond the threshold National Environment Protection Measures level of 50 µg/m³. During the 1994 Sydney bushfires, the peak was 210 µg/m³ (against a background level from non-bushfire sources of 30 µg/m³). During Sydney's Christmas 2001 bushfires particulate levels above 150 µg/m³ were sustained for 10 days. In Canberra the maximum level on 18 January 2003 was 192 µg/m³.¹² The adverse health effects of particulate pollution are now well accepted. For example, although there were no direct deaths from the Sydney fires in 2001, Australia's Environment Protection Association (EPA) estimated that particulate pollution generated by the bushfires would have been responsible for 16 deaths and at least 30 admissions to hospital for cardiovascular and respiratory conditions among the population of Sydney¹⁵.

Mitigation and response: learning to live with fire

If we accept that fire is an essential and recurring part of our landscape, how can we learn to live with it? One response to better equip ourselves to deal with the disasters by investing more in fire fighting skills, expertise, co-ordination and sophisticated equipment such as fire bombing aircraft. Indeed, the Commonwealth of Australian Government (COAG) report commissioned after the 2002-03 fire disasters in South Eastern Australia made many such recommendations to improve disaster response around Australia¹⁶. In addition to this the report examined options for mitigation of disasters. They suggested that the first step is a better understanding of the complexity of the problem at all levels in the community and made many recommendations for education of all sections of the community. Of paramount importance is overcoming the widespread misplaced attitudes of 'warfare' against fire with its implicit, yet ecologically impossible, aim of total fire suppression in our landscapes. The need for this was well articulated by Campbell¹⁷

We have to get over the perpetual characterisation of wild fire in Australia as a terrifying aberration, an ineluctable, unpredictable Act of God, and start to see it and manage it as an inherently Australian phenomenon that goes with the territory. Fire is a crucial shaper of many of our landscapes and a valuable resource management tool. Rather than demonising fire with the language of warfare, disaster, destruction and terror, we should have explicit programs that are about learning to live with fire ...

Central to all the recommendations was a call for a greater emphasis on further landscape scale research, including the ecological impacts of differing fire regimes in different settings and, coming full circle after 200 years of denial, recognition of the importance of Indigenous fire usage. The COAG reported noted the following:

There is considerable potential for both Indigenous and non-Indigenous Australians to benefit substantially from better understanding of Indigenous Australians' knowledge and use of fire and of how this might be adapted and implemented in contemporary Australia. Such research—much of which would be action oriented and be conducted in partnership with Indigenous Australians—should include a focus on the process of co-learning between Indigenous and non-Indigenous Australians, and on operationally feasible ways of integrating customary and modern practices and technologies to support bushfire mitigation and management.¹⁶

Recently Bowman *et al*^{18 19} undertook a major fire ecology project in collaboration with Aboriginal land owners in northern Australia. They observed that Aboriginal burning created a

fine-scale mosaic of burnt and unburnt areas with a lower frequency and scale of burning compared to European fire regimes. In contrast the European systems were characterised by fires of annual or biennial frequencies and burn large areas that appear to have triggered a positive feedback cycle between fire frequency and flammable grass fuels. They concluded that the preservation of Aboriginal fire management regimes should be a high management priority given the difficulty to break the grass-fire cycle once it has been initiated. They also noted that current Aboriginal landscape burning has a significant impact on vegetation structure, but little effect on either species composition or total tree density apart from a lower biomass of tall grasses and a greater abundance of the fire sensitive tree *Callitris intratropica*. Their work provides important empirical corroboration of previous descriptive ethnographic and historical analyses that vegetation structure at the time of settlement was strongly influenced by Indigenous peoples' use of fire. On the basis of this research we have commenced a project to evaluate further Aboriginal land management, the nexus with human health and well-being and the health of their country.²⁰

Never ending reports and the prescribed burning debate

The COAG Inquiry is part of a long tradition of investigations commissioned to examine events and make recommendations for future practice following devastating fires in south eastern Australia such as that which occurred in 2002–03. Other recent reports have included the McLeod report (ACT),²¹ the Esplin Report (Victoria)²² and a federal parliamentary inquiry²³. The call for greater prescribed burning has been almost unanimous among them. As the House of Representatives Select Committee on the inquiry into the bushfires noted in its foreword "The Committee heard a consistent message right around Australia: there has been grossly inadequate hazard reduction burning on public lands for far too long".

Calls for more deliberate burning are not new. The Royal Commission that followed the Victorian fires of 1939 identified inadequate prescribed burning as an important reason that the 1939 fires in Victoria were so intense and destructive. Justice Stretton put this down to inadequate staffing of land management agencies and the attitudes of foresters who were "averse to burning of any sort" concluding that the Forests Commission must recognise the necessity for protective burning.²⁴ Similarly in 1992 the Chief Fire Officer in Victoria argued for a systemic role for fuel reduction and ecological burns²⁵. Guidelines and policies for prescribed burning have been developed in some jurisdictions including Western Australia²⁶ and have been used for many years in the United States.²⁷

Management agencies have responded to these calls. For example Parks Victoria doubled the amount of prescribed burning before the 2003–2004 fire season compared with previous efforts.²² However, while landscape researchers and management agencies are clearly moving towards more pro-active land management with an increased emphasis on deliberate burning, other sections of the community are not necessarily following.

Ecological trade-offs with prescribed burning

Michael Organ included a dissenting report within the COAG Inquiry that expressed caution about increasing prescribed burning. He supported calls by environmental organisations for further research into the role of climate change in producing a greater frequency of extreme fire danger days and the ecological costs and benefits of different fuel reduction regimes.¹⁶ The debate has been characterised by a 'great divide' between foresters and farmers on one side and environmentalists on the other.²⁸ Indeed, many environment groups have expressed concern that increased prescribed burning is now being promoted as a panacea without sufficient emphasis on research about potential harmful ecological impacts of either inadequate or excessive burning.²⁹ For instance compared to infrequent fires (both planned and unplanned),

frequent hazard reduction has potentially negative effects such as disadvantaging plant species that need a substantial fire-free period for seed-set or animals that need unburnt habitat to nest.

These concerns need to be balanced against the potential ecological harms of the current mode of disaster response. For instance, the last resort for fire fighters confronted with high-intensity wildfires in areas of heavy fuel loads is to 'back-burn', often from hastily constructed fire-breaks (wide strips of bare earth) that have their own ecological costs such as subsequent weed invasion and soil erosion. Back-burning has the unavoidable effect of sandwiching the resident wildlife between two converging walls of fire which is far worse than a single fire front. Emergency back-burning is particularly destructive in bushland fragments around urban areas. Once wildlife is eliminated from a bushland fragment, natural recolonisation is often impossible because of isolation by lethal 'rivers' of speeding motor vehicles.³⁰

There are other aspects to this debate including the feasibility of safely performing enough burns. For example Mcleod noted that when weather conditions are taken into account as few as 25 to 30 days a year (including weekends) might be assessed as suitable in eastern Australia and only 18 days per annum for Canberra.²¹ Inevitably some prescribed burns will escape control and turn into wildfires: fire is by nature a risky substrate.

Health trade-offs with prescribed burning

The COAG report also noted a new dimension in the prescribed burning discourse that has received little attention in previous reports; that is the trade-off between tolerating reduced air quality and achieving risk reduction by fuel-reduction burning¹². It received submissions from groups such as Advocates for Clean Air which passionately argued against further polluting the air with bushfire smoke. Quoting reputable sources including the American Lung Association and both the Australian and US Environment Protection agencies they pointed out the high proportion of people who are at risk of illness and death from increases in particulate air pollution.³¹

This has been an area that land managers and bushfire researchers have historically been loath to address. In 1992 Incoll²⁵ bolstered his case for prescribed burning by quoting a medical review by Streeton that concluded that "it would seem unlikely that the general run of particles, the main pollutant in bushfire smoke, represented any real risk to human health".³² Smoke was considered a nuisance and an eyesore, but not harmful when compared to industrial smog. What is not well understood by many current fire managers is that there have since been considerable advances in medical research about the adverse health effects of particulate air pollution. For example Stretton's second review for the EPA just five years later came to very different conclusions from his first, as much new evidence became available during the 1990s.³³ It is now well accepted that particulate air pollution is associated with short and long term mortality, particularly among the elderly and those with pre-existing heart and lung disease, neonatal mortality and many lung and heart diseases, including ischemic heart disease. Most studies describe linear relationships with these health outcomes with no apparent lower threshold.³⁴

However, there is very little information specifically concerning particulates and other pollutants generated by vegetation fires as such studies are difficult to conduct for practical reasons. While there is more information about pollution generated by wood burning for residential heating, another source of biomass smoke, most research has examined particulate pollution generated by the combustion of fossil fuels by industry and motor vehicles. However, the limited available evidence would suggest that particulates from biomass combustion are no less harmful than particulates originating from the combustion of fossil fuels. Of the dozen published studies of pollution from wildfires, only 3 have failed to show any association between excessive smoke pollution and adverse health outcomes³⁵. One large review compared

the magnitude of adverse health outcomes of exposure to particulates largely derived from wood smoke with particulates mostly derived from fossil fuel combustion and concluded that particulates derived from wood smoke might be more injurious to human health.³⁶

These studies exacerbate the difficult trade-offs faced by fire managers who are being urged to burn more and more and knowingly expose large populations to low levels of poisonous substances. While there are genuine grounds for concern, the actual level of risk this represents is uncertain. However, nearly every capital city is adjacent to large tracts of bush land and the public is becoming better informed about and more wary of air pollution. For the first time urban dwellers are beginning to realise that they have a direct and immediate stake in how land is managed and politicians, who tend to be driven more by constraining health budgets than issues of biodiversity, are also beginning to take interest.

The Darwin Study

Thus there have been increasing calls for more research into the health effects of bushfire smoke, particularly at low levels under the EPM target threshold of 50 $\mu\text{g}/\text{m}^3$ ³⁷. Our current research program is designed specifically to address this question. Darwin has many advantages for such research: it has a seven-month rain free dry season characterised by continuous fires in the surrounding savanna vegetation providing a continuous background of smoke pollution with peaks and troughs over several months, there is no significant source of atmospheric air pollution other than particulates derived from wildfires³⁸ and there is a single major hospital that has systematic data collection systems in place. Our pilot study demonstrated significant increase in asthma presentations to hospital with each 10 $\mu\text{g}/\text{m}^3$ increase particulates measured as PM10. When the PM10 data were aggregated into 10 $\mu\text{g}/\text{m}^3$ classes the modelling demonstrated a threshold at 40 $\mu\text{g}/\text{m}^3$ where presentations for asthma increased 2.6 times relative to the baseline category of less than 10 $\mu\text{g}/\text{m}^3$ ³⁹. As part of our current large study we are now examining a wide range of both health and ecological outcomes in detail, including the consequences of contrasting land management activities with regard to fire regimes, ecological impacts, levels of pollution and smoke dispersal.

Dealing with complex trade-offs and forging new alliances

Regardless of these ecological and health debates, unplanned wildfires will continue to be a part of life. Every management action from doing nothing, to implementing extensive intervention programs, will involve important health, economic and ecological trade-offs, and which will vary from region to region. While Australians are increasingly aware of their evolutionary heritage, beginning to understand the fundamental ecological role of fire in our landscapes and are grappling with the management implications of this, we still have a long way to go. It could be argued that we have reached a fourth age of fire: adaptation. That is, adaptive management based on balancing risk and costs through rational analysis, research and evaluation of the efficacy of land management programs success and failures.

Bushfires are clearly an excellent example of the complexities associated with the quest for sustainable relationships between ecosystems human welfare. An increasing frequency of severe vegetation fire events throughout the world is just one example of the global change that is confronting human societies today⁴⁰. While the problem of wild fires is apparent to all members of society and we are making progress in addressing the issues, many other major ecological problems are less obvious, particularly to decision makers in large urban centres. Jared Diamond, in a great example of transdisciplinary scholarship, has recently described five major factors that contribute to the collapse of established societies⁴¹. These being: climate change, hostile neighbours, few trade partners, environmental problems, and a society's response to its environmental problems. He argues that while the first four may or may not prove significant in any individual case study the fifth always does.

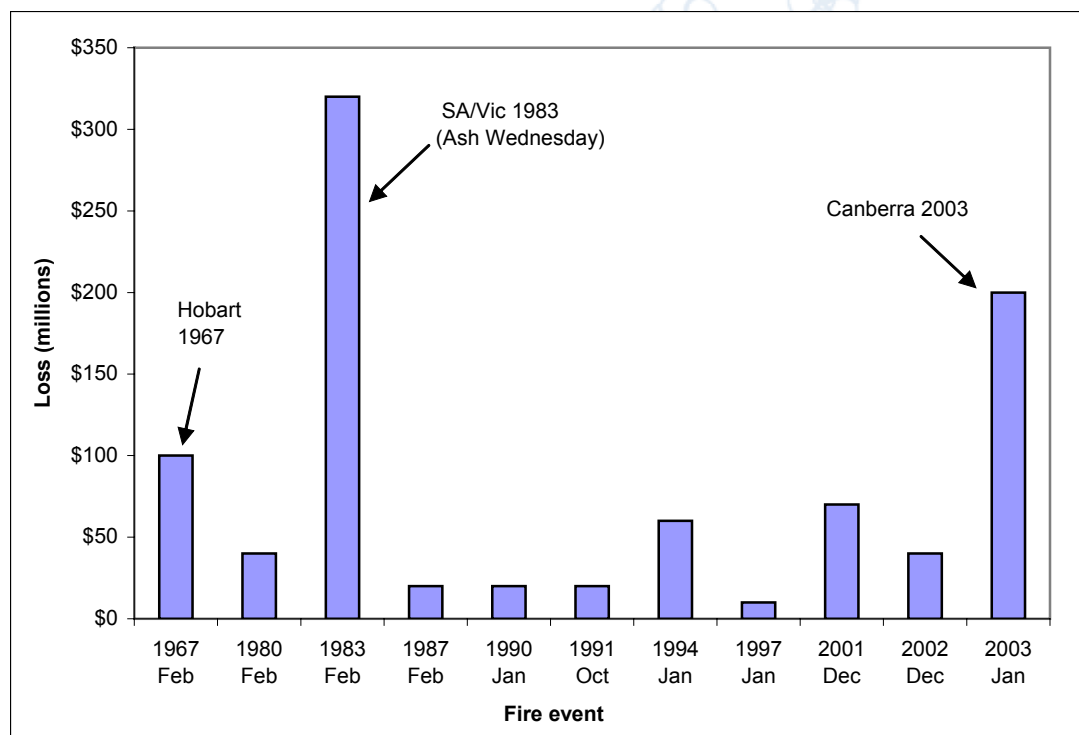
There is no doubt that society's response to the world's many environmental crises will be crucial to our current and future well-being. This demands transdisciplinary research that is action orientated, adaptive and built from a constituency in many different communities and perspectives including rural health practitioners and researchers, land managers and ecologists. To be effective such research requires effort and a willingness to venture outside a disciplinary comfort zone – this is both frightening and rewarding. We are all on an adaptive journey.

Figure 1 Schematic representation of the "three great ages of fire in Australia" in a hypothetical tract of tropical *Eucalyptus* savanna³



(a) 'Wild' In the pre-human period, lightning started fires infrequently and burnt large areas, creating a coarse habitat mosaic to which various species of birds and mammals had become adapted. (b) 'Tamed' Aboriginal fire management was characterised by a high frequency of fires that burnt much smaller areas, producing a fine-scale habitat mosaic that supported most of the pre-human wildlife assemblage. (c) 'Feral' Under European fire management, fires, that had a similar frequency as the Aboriginal period, burnt large areas thereby obliterating the pre-existing habitat mosaic created by Aboriginal landscape burning.

Figure 2 Losses estimated by the Insurance Council of Australia from major bushfires since 1967 and adjusted to \$2001



Adapted from Aon Re Update 2003¹²

REFERENCES

- 1 Wilcox BA et al. EcoHealth: A transdisciplinary imperative for a sustainable future. (editorial) *EcoHealth* 2004;1:3-5
- 2 Lebel J. Health: An ecosystems approach. Canada International Development Research Centre. Ottawa. 2003. http://web.idrc.ca/en/ev-29393-201-1-DO_TOPIC.html viewed Feb 2005.
- 3 Bowman DMJS. Bushfires: a Darwinian perspective. In Cary,G., Lindenmayer, D., Mackey, B. and Dovers, S. (eds) Australian burning – the future of fire. 2003. CSIRO publishing.
- 4 Bowler JM. Aridity in the late tertiary and quaternary of Australia. In: Evolution of the flora and fauna of arid Australia. WR Barker and PJM Greenslade, Eds Peacock Publications Adelaide. 1982:35-45.
- 5 Bowman DMJS. The Australian summer monsoon: a biogeographic perspective. *Australian Geographic Studies* 2002;40:261-277.
- 6 Miller GHF, Magee JW, Johnson BJ, Fogel ML, Spooner NA, McCulloch MT and Ayliffe LK. Pleistocene extinction of *Genyornis newtoni*: human impact on Australian megafauna. *Science* 1999;283:205-208.
- 7 Franklin DC. Evidence of disarray amongst granivorous bird assemblages in the savannas of northern Australia, a region of sparse human settlement. *Biological Conservation*. 1999;90:53-68.
- 8 Woinarski JCZ, Milne DJ and Wanganeen G. Changes in mammal populations in the relatively intact landscapes of Kakadu National Park, Northern Territory, Australia. *Austral Ecology* 2001;26:360-370.
- 9 Gilmore M. Old Days: Old Ways. Angus and Robertson 1934. republished 1985:152-153.
- 10 Barr N and Carey J. Greening a brown land: the search for sustainable land use. MacMillan. Melbourne 1991.
- 11 Baker, R. Land is Life: from bush to town - the story of the Yanyuwa people. Allen and Unwin. 1999:262.
- 12 Ellis S, Kanowski P and Whelan R. National Inquiry on Bushfire Mitigation and Management, Commonwealth of Australia, Canberra. 2004 <http://www.coagbushfireenquiry.gov.au/findings.htm> viewed February 2005.
- 13 Clayer JR, Bookless-Pratz C and Harris RL. Some health consequences of a natural disaster. *Med J Aust*. 1985;143(5):182-4.
- 14 McFarlane AC, Clayer JR and Bookless CL. Psychiatric morbidity following a natural disaster: an Australian bushfire. *Soc Psychiatry Psychiatr Epidemiol*. 1997;32(5):261-8.
- 15 National Environment Protection Council. National Environment Protection (Ambient Air Quality) Measure Impact Statement for PM2.5 Variation. Setting a PM2.5 Standard in Australia. 2002. http://www.ephc.gov.au/pdf/Air_Variation_PM25/draft_variation_is.pdf viewed Feb 17 2005.
- 16 Ellis, S, Kanowski, P and Whelan, R . National Inquiry on Bushfire Mitigation and Management, Commonwealth of Australia, Canberra. 2004:83. <http://www.coagbushfireenquiry.gov.au/findings.htm>
- 17 Campbell A . Learning to live with fire. in Cary G, Lindenmayer D and Dovers S. (eds) Australia Burning: fire ecology, policy and management issues. CSIRO Publishing, Melbourne. 2003.
- 18 Bowman DMJS, Walsh A and Prior LD. Landscape analysis of Aboriginal fire management in Central Arnhem Land, north Australia *Journal of Biogeography* 2004;31:207-223.

- 19 Bowman DMJS and Prior LD. Impact of Aboriginal landscape burning on woody vegetation in *Eucalyptus tetrodonta* savanna in Arnhem Land, northern Australia *Journal of Biogeography* 2004;31:807-817.
- 20 Burgess CP, Johnston FH, Bowman DMJS and Whitehead P. Healthy land health people: exploring the health benefits of Indigenous natural resource management. *Australian and New Zealand Journal of Public Health*:2005 in press.
- 21 McCleod, R. Inquiry into the Operational Response to the January 2003 Bushfires in the ACT . Canberra. 2003.
- 22 Parks Victoria. Annual Report. Victorian Government Printer. Melbourne. 2003
http://www.parkweb.vic.gov.au/resources/mresources/ar_2004/prescribed_burning.html viewed 5 Feb 2005.
- 23 Nairn, G. MP Chair. A Nation Charred: Report on the inquiry into bushfires. House of Representatives Select Committee into the recent Australian bushfires. Commonwealth of Australia. Canberra 2003. <http://www.aph.gov.au/house/committee/bushfires/inquiry/report/front.pdf> viewed 5 Feb 2005.
- 24 Stretton LEB. Report of the Royal Commission to inquire into the causes of and measures taken to prevent the bush fires of January 1939, and to protect life and property. Government Printer. Melbourne. 1939.
- 25 Incoll R. Prescribed fire on public land in Victoria an overview: Report by Chief Fire Officer Dept of Conservation and the Environment to the annual conference of the Australian Association of Rural Fire Authorities. 1992.
http://sres.anu.edu.au/associated/fire/COURSE/5_MANAG/PRESCRIB/pres_pub.HTM viewed 5 Feb 2005.
- 26 Perth Air Quality Management Plan (2002-2030), Department of Conservation and Land Management. Perth. 2002
<http://aqmpweb.enviro.nsw.gov.au/air_quality/Air_Quality_Management_Plan>, viewed 5 Feb 2005.
- 27 United States Environmental Protection Agency. Interim air quality policy on wildland and prescribed fires. U.S. Environmental Protection Agency. 1998.
- 28 Schauble, J. Why there's so much heat from bushfires. *The Age*, 4 August 2004.
<http://www.theage.com.au/articles/2004/08/04/1091557913611.html?from=storylhs&toneclick=true> viewed 5 Feb 2005.
- 29 Fleming T and Cohen S. Kosciuszko - and the burning issue of hazard reduction. *National Parks Journal*. 2003;47(2) <http://www.npansw.org.au/web/journal/200304/features-fire.htm> viewed 5 Feb 2005.
- 30 Bowman DMJS. Living with fire. *Australian Nature Magazine*. 2002;84.
- 31 Advocates for Clean Air. Submission to the Council of Australian Governments Bushfire Inquiry. 2003. http://www.coagbushfireenquiry.gov.au/subs_html/gayle_crosett.html viewed 5 Feb 2005.
- 32 Streeton JA. Air pollution health effects and air quality objectives in Victoria. Consultant's Report to Environment Protection Authority. 97pp. Melbourne. 1990.
- 33 Streeton JA. A review of the existing data on six air pollutants. Report to the National Environment Protection Council, Australia. 1997.
- 34 Katsouyanni, K., Ambient air pollution and health, in Impact of environmental pollution on health. in Briggs DJ, Joffe M, and Elliott P. Editors. *British Medical Bulletin*: Glasgow. 2003:143-157.

- 35 Bowman DMJS and Johnston FH. Wildfire Smoke, Fire Management, and Human Health EcoHealth. Published online: 14 February 2005
www.springerlink.com/app/home/contribution.asp?wasp=c96e78b4wr5qvve90dcb&referrer=parent&backto=issue.3.14;journal.1.7;linkingpublicationresults.1:110812.1, viewed 15 Feb2005.
- 36 Boman BC, Forsberg AB, Jarvholm BG. Adverse health effects from ambient air pollution in relation to residential wood combustion in modern society. *Scandinavian Journal of Work, Environment and Health*. 2003;29:251-60.
- 37 Lewis P and Corbett S. Bushfires, air pollution and asthma. *Medical Journal of Australia* 2002;176:517
- 38 CSIRO Atmospheric Research. A Pilot Study of Air Quality in Darwin NT. Northern Territory Government Department of Lands Planning and Environment, Darwin. 2001
<http://www.lpe.nt.gov.au/enviro/wmpcreg/AirO/AQStudy/AQStudy.pdf>, viewed 5 Feb 2005.
- 39 Johnston F, Kavanagh A, Bowman D, Scott R. Bushfire smoke and asthma: an ecological study. *Medical Journal of Australia* 2002;176:535-538
- 40 Schwela, D. Fire disasters: The WHO-UNEP-WMO health guidelines for vegetation fire events. *Annals of Burns and Fire Disasters*. 2001;XIV(4)
- 41 Diamond, J. *Collapse: How Societies Choose to Fail or Succeed*. Viking Books January 2005.
- 42 Aon Re Ltd. The January 2003 Canberra Bushfires. Aon Re Australia Ltd. 2003.
www.aon.com.au/pdf/reinsurance/canberra_bushfires_jan_2003.pdf viewed 5 Feb 2005.