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FIRE! The Australian Experience

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Introduction

"The foure elementes menace alle men that thanke not god," claimed Caxton in the fifteenth century. Today we must not be thanking God enough, for those four elements - earth, water, air and fire - still dominate the "menacing" side of our daily news, whether it be Hurricane Floyd in the United States, last week's devastating earthquake in Taiwan or the increasingly dramatic floods of recent times in mainland China.

Australia's balance of the four elements is distinctive. Our earth is relatively stable, compared with our neighbours, although let us not forget Newcastle's unexpected earthquake a decade ago. Our water has not often been sufficient to cause floods of Amazonian proportions, although Brisbane still remains unconvinced that floods of 1974 levels might not happen again, and the New South Wales town of Nyngan has already seen a near-repetition of its most serious floods of 1990. Cyclone Tracey, likewise, reminds us that it is only a matter of time before Darwin, or another northern Australian city, is subjected to a similar force of nature's air.

It is, however, fire which strikes the greatest fear into the hearts of Australians, both rural and urban dwellers. Fire seems to be our nationally defining element. Fire, because of its particular encouragement by our driest of continents; fire, because of its unpredictability and fickleness, especially when combined with air. Memories of Black Friday in January 1939 and Ash Wednesday of February 1983 still scar the lives of many Victorians and South Australians, while Hobart's recollection of its suburban disaster of 1967 remains keen. Recent years have shown that even the closer-in North Shore suburbs of Sydney are not immune from fire's ravages. Fire, we so often conceive as the destroyer, the devourer. Bushfire still remains a major and persistent threat to the lives of Australians. But we do need fire, as part of so many cycles of nature's regeneration, as a nurturer and life-giver. Its management rather than its eradication is the order of the day.

The National Academies Forum is a collaborative body of the four learned Academies - Science, Technological Sciences and Engineering, the Humanities, and Social Sciences. The Forum's members come together to support or to mount ventures which cross the disciplinary boundaries that distinguish the individual Academies, and to foster common interests in the furtherance of research, scholarship and community debate. Over the last three months the Forum has been joint sponsor of the Pacific Science Congress in Sydney, has co-hosted with the National Library a symposium in Canberra entitled "Scholarship, Intellectual Ownership and the Law", and has held meetings of Fellows in each State to debate the Federal Government's discussion paper New Knowledge, New Opportunities. In mounting this Adelaide symposium on the Australian experience of fire, the Forum has wanted to promote the broadest possible range of perspectives offered by its four disciplinary areas. Speakers today and tomorrow will take us above, below, and even into fires, and look at their predictions and their aftermaths. We shall debate the training of firefighters, the motives of arsonists, and the counselling of those whose possessions and loved ones fire destroys. And we shall look at how Australian arts, both indigenous and other, have represented fire, and how the media becomes participant in the prevention, and sometimes the cause, of fires.

While I leave it to Mr Martin Thomas, Vice-President of the Academy of Technological Sciences and Engineering, to draw out conclusions from this symposium before lunch tomorrow, I suggest at its very start that our speakers do share some common understandings, namely:

- that environmental, atmospheric and commercial demands are often in conflict, where fire is concerned, and that, as the annual smoke hazes across South-East Asia demonstrate, their reconciliation is difficult. Fire knows precious few boundaries.

- that constant education is needed for better land management, both to prevent damaging fires and to use fire as a nurturing force. Here Australia's indigenous peoples still have much to teach the nation.

- that Australia must escalate its investment in fire-related research and development. While much can be learned from overseas research, many Australian circumstances of fire are peculiar to our continent. They require strong Australian research into better prediction, detection and management systems.

- that Australia can never be complacent about fire. Each year brings with it new and unexpected challenges, which we often only surmount after much loss of property and, sometimes, life.

Perhaps these understandings might be the basis for some conclusions or resolutions for action to emerge from this symposium.

I take this opportunity to thank the supporters of this symposium, in particular major sponsor, the Bureau of Meteorology, sponsor, the Victorian Department of Natural Resources and Environment, and our host, the University of Adelaide and its Vice-Chancellor, Professor Mary O'Kane. We are most grateful to the Organizing Committee, chaired by Professor Peter Schwerdtfeger, for its development of this exciting and varied programme, and to the staff of the Australian Academy of Technological Sciences and Engineering, notably Mrs Joy Dudine and Ms Kylie Hall, for their organisation, administration and promotion of the symposium.

Professor Malcolm Gillies

President, National Academies Forum

"The fire at the centre of each family": Aboriginal traditional fire regimes and the challenges for reproducing ancient fire management in the protected areas of northern Australia

Professor Marcia Langton[1]

ABSTRACT

Fire has played a significant role in the shaping of the Australian landmass and its biota. It is an ancient elemental force, constructed as a powerful cultural and religious symbol by Aboriginal peoples in Australia, and a key tool for the reproduction of landscapes, particularly in northern Australia. Since the arrival of settler Australians and their confrontation with the 'burning rage' of the Australian landscape, fear of wildfire has motivated a repression of Aboriginal burning practices in most parts of Australia. Researchers from the Aboriginal domain have nevertheless been able to report during the 1970s and 1980s, on the continuance of traditional Aboriginal burning regimes and their impact on the landscape. Current understandings of these seasonal fire management traditions is that they permit reproduction of fire-dependent floral species, and through the creation of buffer zones, protect fire-intolerant floral communities such as monsoon forests.

For these landscape mosaics in remote Australia, the most significant disruptive factor during the colonial era and during much of this century, has been the removal of Aboriginal societies, whether by violence, forced removals or enticement of small groups to government settlements. The absence of traditional groups to carry out the annual and seasonal mosaic burns has turned some of these areas into "the new wilderness" described by Bowman: areas where wildfires, fuelled by accumulated grasses and undergrowth, cause extensive damage.

During the last decade, Federal National Park authorities and some State authorities have developed policies for reproducing Aboriginal fire management practices in order to maintain the landscapes of the wet-dry tropics and the arid zone. In a few cases, these efforts have been carried out in collaboration with the traditional Aboriginal owners of the relevant areas.

This paper surveys the fire management plans in the available Plans of Management and Draft Plans of Management of national parks where there is an indigenous presence, and in some cases, substantial interests in the parks. This survey of fire management in National Parks shows that marked relevance of Aboriginal knowledge of ecological systems and the use of fire to the challenge of managing vast regions of the National Park estate and Aboriginal land in northern and arid Australia. Scientific research conducted in collaboration with traditional Aboriginal owners in the northern tropical savannas has played a key role in the joint management regimes in National Parks where customary Aboriginal landscape burning is promoted to conserve biodiversity.

1 INTRODUCTION: LANDSCAPES OF THE ANCIENTS

Fire has been an ecologically significant factor in the evolution of Australian biota. The research record makes it clear that, beyond this simplistic assertion, the evidence on the impact of human and natural fires on the natural environment is substantial and complex, and often contentious. It is uncontestable, however, that Aboriginal people, arriving from at least 60,000 years ago, used fire to control natural fire; contemporary Aboriginal groups predict the behaviour and spatial extent of fire, and burn seasonally to create habitat mosaics. This very long period of Aboriginal landscape burning presents particular problems for the scientists, social scientists and land managers in the field of biodiversity conservation and sustainable development.

For 65 million years since the separation from Gondwana about 60 million years ago, the continent drifted slowly north during which time the vegetation evolved from the ancestral Gondwanan stock into

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the distinctive Australian plant communities we know today. The continent dried gradually, the climate altering in millennia-long cycles from wetter to drier with the glacials freezing the lands and seas and interglacials defrosting the seas which rose to form, ten thousand years ago, the fabled Great South Land, *Terra Australis*[1]. For the last ten million years, as the continent drifted northwards away from Gondwana, into the warmer latitudes, the incidence of lightning strike increased igniting regular wildfires. Over geological time these fires had a major influence on the evolution of the plants and their communities.[2]

When early human groups settled Australia, 60,000 years ago[3], the natural fire regime was altered from lightning-induced fires to human-induced fires. When fire became a tool in the human repertoire of material and social culture the incidence of deliberate fires increased. The emerging evidence for Northern Australia is that Aboriginal people have preserved monsoonal rainforests against the climatic imperatives with their seasonal fire regimes; and that they have maintained habitats and populations which are fire-dependent or fire sensitive. The prevalence of fire-tolerant species over much of the northern savannas may be the result of millennia of systematic burning. However, some of the propositions in the literature as to the impact of Aboriginal landscape burning in prehistoric times are speculative, as Bowman (1998:400) points out:

> Currently, it is impossible conclusively to demonstrate the effects of Aboriginal landscape burning in the prehistoric past given the vague time frames available to understand Aboriginal demographics such as settlement patterns and waves of colonization. More problematic is an inherent circularity concerning cause and effect of climatic change[,] vegetation change, and burning through the late Quarternary period ... Clearly, peaks of microscopic charcoal particles in pollen cores cannot be treated as an unambiguous indicator of Aboriginal landscape burning ... Indeed, Horton (1982) believes the inconsistent charcoal-particle response in pollen cores to the presumed presence or absence of Aborigines demonstrates that microscopic charcoal particles cannot resolve the effect of Aboriginal landscape burning on the environment. To date, this criticism has not been rebuffed. The palaeoecological impacts of Aboriginal burning may never be possible to determine because “it is impossible to hold all other variables constant” (Head, 1989).

It is the widely accepted view that although fire was common throughout the world, nowhere else has it had such a dramatic effect in reshaping an entire continent, than in Australia. Since settlement of Australia by humans over 60,000 years ago the fire regime has been changed. The European invasion just over 200 years ago changed the fire regime yet again, with destructive results.

The most extreme colonial impact, whether as a result of settler violence, or disease, or incarceration of groups in administered reserves, was the rapid reduction of the Aboriginal population, resulting in some areas in the extinction of whole language groups. The consequence of this history for the relationship between fire and biodiversity is that wherever there are no longer Aboriginal societies practising traditional land management regimes, by using fire, wildfires fuelled by uncontrolled fuel loads sweep across the land with highly detrimental impacts on flora and fauna. The landscape mosaics typical of remote Australia, where such indigenous societies survive, are created by seasonal, regular reduction of these fuel loads by indigenous groups which continue their hunting and gathering subsistence lifestyles to a greater or lesser extent. The absence of traditional groups to carry out the annual and seasonal mosaic burns has turned some of these areas into “the new wilderness” described by Bowman: areas where wildfires, fuelled by accumulated grasses and undergrowth, cause extensive damage.

Our knowledge of Aboriginal landscape burning is greatest where Aboriginal affiliations with landscape continue, partial where the frontier impact society did not substantially impair Aboriginal societies, and least where the impact of the frontier caused the demise of indigenous societies. The extent of research in the wet-dry tropics, the wet tropics, and the tropical savannas, all in northern Australia, much of which was colonised only in this century, is coincident with these historical impacts of the frontier. Andersen and McKaige, citing a range of sources, describe the context of fire in northern Australia, in this way:

> The dominant vegetation type of northern Australia is tropical savanna, featuring a dense grass layer occurring in association with sparse trees, as is the case throughout the tropical world wherever rainfall is highly seasonal. The profuse grass production of the wet season becomes tinder dry over the ensuing dry season, making fire an annual occurrence in savanna biomes. Most savannas elsewhere in the world

> are highly modified by people, and fires are lit primarily in the context of land clearing and livestock production. Australian savannas, on the other hand, are largely uncleared, and fires are lit primarily in a conservation or Aboriginal land management context. (Forthcoming: 2)

Research also demonstrates that the inability of Aboriginal groups to return to their traditional estates following colonisation has meant a change in seasonal fire regimes and thus a failure of fire-dependent species to reproduce and in these areas, the accumulation of fuel loads unrestricted by traditional Aboriginal fire. The legal suppression of Aboriginal fire use and the historical removal or extinction of Aboriginal groups from many areas has resulted in the absence of the annual Aboriginal fire control and fuel reduction, resulting in wildfires with devastating impacts on biodiversity and mosaic habitats. These areas have been called by Bowman, the "new wilderness".

On Aboriginal land and in some National Parks, particularly those under Commonwealth Management, Aboriginal fire management has been recognised as an essential component of land management plans for the maintenance of biodiversity. Where traditional groups no longer reside on or use areas of Aboriginal land, attempts are being made to replicate Aboriginal mosaic burning by re-introducing Aboriginal people to land (see Cooke, 1998) and similar programs of replicating the traditional landscape on non-Aboriginal use aerial fire bombing.

Using geographic information systems and satellite imaging a group of scientists and land managers, whose efforts are linked to the Cooperative Research Centre for Sustainable Tropical Savannas, are mapping fire incidence across the north to develop a sophisticated picture of wildfire-prone and fire-managed areas.

Political mischief has been caused by interest groups by conflating highly contentious speculation about the role of fire ignited by early human colonists on the extinction of the megafauna and the use of fire, especially in the rangelands, by contemporary Aboriginal groups. Bowman (1998: 404) concluded in his survey of the evidence that "there remains much to understand."

> Although there remain great uncertainties and gaps in knowledge, the available evidence leaves little doubt that Aboriginal burning was skilful, and was central to the maintenance of the landscapes colonized by Europeans in the 19th century. However, it is unclear if Aborigines had a more systematic and predictive ecological knowledge of the consequences of their use of fire. What is required is an advance from the poetic concept of fire-stick farming (Jones, 1969) to a coherent scientific analysis of Aboriginal burning that can be used to buttress land-management prescriptions. . . In environments where Aborigines maintain close links with the land, there is an urgent need directly to involve Aboriginal people, especially the older ones, in collaborative research on the fire ecology of various ecosystems.

The motivations for the misuse of contentious palaeoecological research on human fire and the extinction of species before European colonisation are various. Euro-Australian pastoralist political dominance in the remote areas where Aboriginal populations are proportionately high creates pressures on many land management agencies to suppress Aboriginal burning. The replacement of Aboriginal landscape management regimes with Euro-Australian pastoralist economy across the greater majority of Australian rangelands has had a massively detrimental impact on Australian biodiversity. Scientists have estimated the rate of extinction of mammal populations in Australia in the last century to be among the highest in the world.

The pursuit of corporate wealth creation opportunities from Australia's vast mineral resources is another potent factor in the debate. For instance, the extension of uranium mining in the World Heritage Area of Kakadu National Park, has given rise to intense political debate, accompanied by much vilification of Aboriginal land management regimes. The application of research findings in land management strategies in this field is fraught with political tension.

In all but one of the seven Australian State and Territory jurisdictions, Aboriginal people face imprisonment and fines for burning landscapes according to their traditions. Despite the legal repression, Aborigines continue to burn landscapes for a variety of reasons in a number of jurisdictions. Only in the Northern Territory does a federal statute override Territory legislation to permit the occupation, use, and enjoyment of Aboriginal land, according to tradition and custom. Such land is held by Aboriginal Land Trusts. Two national parks jointly administered by a federal agency and Aboriginal traditional owners, are located on such Aboriginal land, under lease Agreements, and here also, Aboriginal burning according to tradition is permitted.

This paper surveys the fire management plans in the available Plans of Management and Draft Plans of Management of national parks where there is an indigenous presence, and in some cases, substantial interests in the parks. The sample is small because of the absence or lack of availability of Plans or Draft Plans of Management for National Parks with an indigenous presence. Notable absences from this survey include the Lakefield and Cliff Islands National Parks, the Jardine National Park, the Simpson Desert National Park and other national parks in the State of Queensland where none of the national parks claimed by Aboriginal people concerned with those areas under the Aboriginal Land Act 1991 have been the subject of title transfers to the Aboriginal claimants. It is understood that there are ongoing policy consideration of the Plans of Management in the Queensland Department of Environment and Heritage.

This survey of fire management in National Parks shows that marked relevance of Aboriginal knowledge of ecological systems and the use of fire to the challenge of managing vast regions of the National Park estate and Aboriginal land in northern and arid Australia. Scientific research conducted in collaboration with traditional Aboriginal owners in the Northern Tropical savannas has played a key role in the joint management regimes in National Parks where customary Aboriginal landscape burning is promoted to conserve biodiversity.

The legal context of fire management is an issue to be considered in assessing the failure to recognise the relevance of Aboriginal fire management in jurisdictions other than the Northern Territory. Aboriginal people in all jurisdictions, except on Aboriginal land in the Northern Territory, risk imprisonment or fines each time they undertake landscape burning. The Aboriginal determination to protect the diversity of habitats and floral and faunal species through mosaic landscape burning in these highly risky circumstances demonstrates the ongoing resistance to ecological transformation of landscapes by large scale European pastoralism, and inappropriate land use in remote Australia.

The fear of Aboriginal people, and of wildfire, in the European population of Australia has an enormous influence on policy outcomes. Scientists are finding that the continuing Aboriginal occupation and use of the landscape preserves biodiversity in some circumstances, while politicians are persuaded rather by popular belief, such as the belief that Aboriginal hunting and gathering poses a greater threat to biodiversity than agriculture. National parks, even though they segregate natural ecosystems from human settlement areas, provide some limited opportunities to introduce research findings to the general public and to permit close contact between the public and phenomena such as Aboriginal mosaic burning, ensuring greater understanding. The potential is greater where responsible authorities pursue these opportunities with vigour, and without fear of political interference.

The extent of Aboriginal ownership of land is a key issue: presently almost 15 per cent of the Australian land mass is owned in various forms by Aboriginal people, largely through land trusts established to recognise customary group ownership of land and to permit the practise of traditions and customs. It is this difference in type of land ownership, that is, mainstream Australian title systems as opposed to statutory Aboriginal customary titles, that lies at the heart of the contestation over fire.

In the last two hundred years, urbanisation, agriculture, pastoralism, industrial and other development have worked radical changes on the distinct Australian environment. These changes were based on the conquest of Aboriginal peoples on the frontiers.

The fate of Aboriginal peoples, construed as "the vanishing race" in this history, is a core idea in visions of the Australian past. The widespread assumption of the complete irrelevance of indigenous systems of knowledge to biodiversity conservation is merely a subset of a wider culture of racism in the Australian polity.[4]

The very idea of an "Australian" landscape throughout much of the Australian continent is based on an erasure, not simply that of nature subsumed and recast by culture, but that of the distinctly Aboriginal landscapes transformed by the frontier and subsequent settlers.

2 FIRE AS CULTURE: ABORIGINAL AND SETTLER SYMBOLS

The cultural importance of fire for Aboriginal people is manifested in the prevalence of fire symbolism. Ceremonial works celebrating the use of fire by ancestral figures and referencing "country" or landscape, and the frequent symbolic references in artistic works is evidence of this: the fire ceremonies[5], Jardiwarnpa and Buluwandi of the Warlpiri, the fire Dreamings[6], the stories which tell of the theft of fire from women in the formative creation period[7], and other cultural symbols of fire such as John Bradley's cultural analysis of Yanyuwa burning practices.[8]

Fire is also one of the elemental signifiers in Aboriginal artistic endeavours: it represents the complex cultural meanings in landscapes and human relationships with landscapes.

It is at the same time feared and repressed by settler Australians who fear it in its wild state. Early European visitors sailing along the northern coastlines remarked on the smoke haze over the Australian continent, and the non-Aboriginal population has come to regard "bushfires" as terrifying "natural" events. Today, tourists express their concern to National Park rangers at the sight of these fires in the northern savanna landscapes where, in some regions, more than half of the landscape is burnt annually. They believe that fires should be immediately extinguished by fire fighters, as they are in the south, because of their threat to property and life.[9]

These have been named, such as "The Ash Wednesday Fires", "Black Thursday", and so on, and have achieved iconic historical status among the new settlers. There is such a fear of fire that its ancient presence shaping the biota of this land is ignored to the extent that a cycle of wildfires and absence of fires occurs with regularity. This problem is best understood in northern Australia, where the tropical savannas remain the least altered of the fire-prone Australian landscapes. While Aboriginal the population today stands at about 260,000 a small minority of Aboriginal people maintain the post-holocene traditions of land management. These societies predominate in the northern and central regions of Australia where the frontier reached only during this century.

It can be deduced that the absence of Aboriginal seasonal mosaic fire regimes across most of Australia has resulted in periodic wildfires. These are managed by modern technological means and result in very high levels of damage to property, death and injury.

Fire incites a range of human emotions. In close proximity to "wild" fires, terror and other degrees of fear are manifested. But there are also feelings of vulnerability and awe. Domesticated fire, the fire of the hearth, evokes rather a sense of comfort, safety, and warmth. Such emotional responses are culturally and historically shaped. Fire is a primeval phenomenon, which has almost certainly been at the centre of human society throughout the history of human evolution.

Hot wildfires which rage through the forested areas of the densely settled southern region in summer are features of Australian life which have achieved iconic status in the general Australian culture. The Ash Wednesday fires were terrifying events for the post World War II generation, but "bushfires" on a similar scale have occurred throughout Australian history.

Several Aboriginal people, writing from their place in traditional Aboriginal cultures, have tried to communicate the profound and fundamental place of fire in Aboriginal constructions of landscape, the physical and the spiritual replenishment that occurs when they use fire, according to their traditions, in their homelands.

Fire is sacred, and its sacredness can be partially apprehended in the many artistic depictions of fire in Aboriginal art. These visual references are often cryptic, as often befits the Aboriginal law of masking sacredness in its public forms. Fire is sacred and yet familiar; it is dangerous and yet a companion, as Dean Yibarbuk explains:

> The secret of fire in our traditional knowledge is that it is a thing that brings the land alive again. When we do burning the whole land comes alive again - it is reborn...
>
> But it is not a thing for people to play with unless they understand the nature of fire.
>
> In my experience here in Central Arnhem Land children learn about fire from their parents and being told stories about who can make fires, different types of burning and the responsibilities of djungkay, the people who help the landowners look after the country and our law. Responsibilities depend on a person's relationship to the landowners of a particular estate. What we call kunred in Kune and wiba in Gurrgoni is called an estate by anthropologists. It is the parcel of land inherited by people through their father's line.
>
> A child's first experiences of fire is being with adults and seeing fires in the landscape (manwurrk) and also the fire that is the centre of each family living area (kunrak). (1998:1)... as they grow, young people learn that fire is more than just something for cooking or hunting - that fire is more than just something for cooking or hunting - that it has a deeper meaning in our culture. As they attend ceremonies with their parents they see and learn to respect the sacred fires that are central physical parts of the most sacred of ceremonies. Importantly, these fires sit between the ceremony grounds where

children and women stay and the more spiritually dangerous ceremony grounds where only senior initiated men go.

Dean Yibarbuk describes the sacred use of fire by men in his country in central Arnhem Land:

> But there is one kind of burning which is men's business alone - and it is dangerous work. This is the fire drive mainly for macropods (the larger ridge dwelling species like kalkberd, djukerre, kandakidj, karndayh) rather than the agile wallabies (kornobolo) which favour monsoon jungle and thicker forest. Emus (wurrbbarn or ngurrurdu) may also be a target for this specialised hunting technique.
>
> There are special places where these hunts traditionally happen. In old times they happened every year and neighbouring groups would wait to be invited to take place, in their turn, perhaps inviting the fire-drive groups to come to their place when, for example, there were many fish to be had from drying billabongs or when their flood plains were ready to burn. These fire drives don't always happen annually now but they still happen regularly.
>
> When the most senior landowner from the area where the fire drive (kunj ken manwurrk = fire for kangaroo) is to be held sees that the time is getting close, he will talk with his senior djungkay. They sit down and discuss how the djungkay will organise the drive - where it will be held, when it will be held (expressed by reference to floral seasonal indicators and moon phases) and who will be invited. Those likely to take part as well as the landowning senior men and their sons will include people from neighbouring estates and/or particular kin, the landowner's uncles, nephews, wife's family and importantly members of the landowners' mother's mother's clan whom he calls kakkak. A number of messengers move out to where other family groups are living to carry the invitation. As they go, they burn unwanted grassland on plains or forest sending up a signal of their approach. The messengers and the invited groups then head for the location for the fire drive, again sending up smoke that marks their travel.
>
> When all the groups have assembled and have camped a night or two and made their plans, a start will be made very early on the appointed morning. The group splits into perhaps four groups of a couple of men. Two go in one direction and the others in the opposite, circling around until they get into pre-arranged positions in a sort of horseshoe shape. According to plan, one fire is lit and others, seeing the smoke, then start walking and lighting the grass as they go. When the semi-circle of flame is lit, the kangaroos are driven to where another large party of maybe ten or twenty men are waiting with shovel-nosed spears.
>
> After the hunt the hunters come back together after the kill. They use smoke from ironwood leaves to ritually purify the game so that it may be eaten by women and children. This is necessary because the fire-drive is itself regarded as a sacred and very serious act, often first enacted by the major creative beings for that area. (Dean Yibarbuk, 1998:1-6)

April Bright[10] made a similar point at the Country in Flames symposium in recounting the fire Dreaming for her country, Kurrindju, in the Maranunggu cultural region in the Northern Territory:

> The chickenhawk - a-titit - took a firestick from a fire that was lit for a big ceremony and flew across Kurrindju, and as he flew across the country he burnt it. His flight path gave us significant areas and his actions began the handing down of one of our responsibilities - burning country. (Bright 1995: 59)

In order to alert the scientific community to the dangers which uncontrolled wildfires pose for these ancient Aboriginal landscapes when fires are lit inappropriately or as a result of the historical removal of Aboriginal landowners from their traditional homelands, Yibarbuk warns:

> Today fire is not being well looked after. Some people, especially younger people who don't know better or who don't care, sometimes just chuck matches anywhere without thinking of the law and culture of respect that we have for fire. This is especially true for people just going for weekends away from the big settlement. Fire is being managed well around the outstations where people live all the time.
>
> The other big problem is large areas of country where no one is living permanently now. Where grasses and fuels are building up, sometimes over a couple of years, until one day someone's little

> hunting fire, or a cigarette chucked out of Toyota gets going and hundreds or thousands of kilometres are burned out in very hot fires.
>
> The bad results of these very hot fires are:
>
> - many fruit trees may be killed
> - animals may be killed or driven away to other country
> - the small unburned habitats that come with mosaic burning and support all kinds of small animals are completely destroyed until they begin to regenerate at the next wet season
> - pockets of jungle (monsoon forest) may be reduced or even destroyed in these kinds of hot fires. If the jungle disappears the yam resources in that area will be gone. There won't be jungle to bring flying foxes.
>
> To go forward we need to encourage our children in the ways of the past. Fire must be managed and people must be on their country to manage that fire. (Yibarbuk, 1998: 6)

Williams, who has worked for 30 years with the Yolngu of northeast Arnhem Land[11], explained notions of Aboriginal relationships with their environments, both juridical and social, as arising "from the religious basis of their proprietary interests in land and the plants and animals that are a part of that environment":

> The relationship is expressed inter alia in terms that have been labeled "traditional ecological knowledge." Within that body of knowledge are embedded the principles and prescriptions for the management of the environment as well as their moral basis. Aboriginal people regard the environment as sentient and as communicating with them ... Distinguishing "natural" from "cultural" or "social" in conceptualising the environment and indeed defining environmental resources becomes problematic in understanding Aboriginal perceptions. Each individual's identity is based on relationships to particular land (and sea, in the case of the Yolngu...). (Williams, 1998:XX??)

The incidents of indigenous knowledge have been described by ethnographers since at least Donald Thomson[12], and have been reported by anthropologists and linguists from many areas of Australia. Jones[13] and Gould[14] were the first to alert the academy to the existence and antiquity of fire as a land management tool among diverse Aboriginal groups. Sylvia Hallam's *Fire and Hearth*[15], which appeared in 1975, built on this early work. More recently, Haynes[16], Russell-Smith and others[17], Latz[18], Bowman[19] and Head and Hughes[20] have provided detailed accounts of Aboriginal fire regimes as they are currently implemented by Aboriginal groups still living on their traditional land, but with different interpretations. Head and Hughes have drawn attention to the use of fire to shape landscapes "to imprint a human signature".

> Aboriginal people have used fire for thousands of years to achieve various objectives, including hunting, regeneration of plant foods, access, controlling snakes and mosquitoes, signaling, warmth and illumination. While much research has focused on economic objectives and the ecological outcomes of fire use, there has also been recognition that fire was widely used to achieve the social objective of fulfilling responsibilities to country… This can involve burning to protect particular sacred sites, but is more generally expressed in the desire to 'clean up the country' and imprint a human signature on it. Country that has been cared for in the proper way is referred to by Ngarinman people in the north-west Northern Territory as 'quiet' country … The Ngarinman contrast quiet country with 'wild', uncared-for-country. 'Quiet country is country in which those who know how to read the signs see human action of the most responsible sort' (Head & Hughes 1996, 279-280).

Thus, it is no longer possible to speak of Aboriginal land use as simple exploitation[21.] Evidence of land management regimes, which reproduced ecosystems and landscape features over millennia, has emerged from these studies:

Russell-Smith with fellow scientists and Aboriginal traditional owners (Russell-Smith et alia, 1997a) conducted a detailed, long term study of Aboriginal resource utilisation and fire management pracice in Western Arnhem Land. They produced a detailed seasonal calendar of landscape burning in Kakadu National Park based on the vast local knowledge of burning and its outcomes in the context of monsoonal climate conditions, the flora and fauna species habitats and behaviour, and fine-grained classification of these phenomena by seasons. This work has been the foundation for management of fire in the Kakadu National Park in Western Arnhem Land and the innovation by Park management to permit parallel fire management systems—both that of the Park regime, discussed later, and the traditional *bininy* landscape burning.

There is ample evidence that Aboriginal people did not take their physical environment as given or immutable, but through purposeful means, actively changed aspects of their environment. Australian populations have used fire for millennia to adapt and reproduce the environment for economic resources as well as land management purposes.

Aboriginal people hold that the possibility of the extinction of a species, whether fauna or flora, or the destruction of what is called "biodiversity" in environment-speak - the existence of myriad living things in complex and partially observable eco-cultures - is offensive to the nature of human existence. Aboriginal people respond to the eradication of feral animals with a similar sense of responsibility felt for the species in its own right. Aboriginal resistance to attempts to suppress their involvement with the natural world, by continuing to burn according to tradition, by organising with experts to sustain biodiversity through weed control, are expressions of these cultural values. Such values sit alongside, and interrogate, the initiatives taken to ensure the viability of Aboriginal culture through incorporation into the global economy and related developments such as the spread of technological infrastructure.

3 THE LEGAL RESTRICTIONS ON ABORIGINAL CUSTOMARY LANDSCAPE BURNING

Australian colonies federated in 1901 under the *Constitution of the Commonwealth of Australia*, provided for in a British Act of Parliament. Whereas in 1901, the *Constitution* provided for trade relations, taxation, governmental, juridical and other arrangements between the six previous colonies, since 1978, there have been seven State and Territory jurisdictions in the federation. The Northern Territory was granted limited self-government by statute at that time. There are, therefore, seven legal jurisdictions, each with its own laws relating to fire control and management, and for the recognition, or suppression, as the case may be, of Aboriginal land ownership and practice of tradition and custom. At the same time, the federal government administers and applies laws as well under Constitutional provisions.

The *Constitution* also provides that Commonwealth law prevails over State and Territory laws to the extent of any inconsistency and that the Commonwealth has law-making power in relation to Aboriginal people. Therefore Commonwealth laws applying to Aboriginal people override State and Territory laws to the extent of any inconsistency.

Because fire and and fire control are not mentioned in the *Constitution*, fire is a State and Territory jurisdiction matter. Section 51 of the *Constitution* sets out the matters over which the Commonwealth has power and by deduction, anything not mentioned or set out or enumerated at Section 51 is a matter over which States and Territories have jurisdiction, and these are matters for their Parliaments.

For the purposes of understanding how the various laws apply in relation to Aboriginal use of fire, it is necessary to look at particular legislation, such as the *Bushfires Act* of the Northern Territory and the *Aboriginal Land Rights (Northern Territory) Act* of the Commonwealth. In the Northern Territory, where, arguably, the protection of Aboriginal customary rights to land and waters is highest, it is the coincidence of the application of both Commonwealth and Territory laws that enables a limited enjoyment of Aboriginal custom in relation to landscape burning. The *Bushfires Act* is a general law passed by the Northern Territory Legislative Assembly to regulate use of fire and prohibits lighting fires without a permit in many circumstances.

The *Bushfires Act* prohibits people from lighting fires and yet under Aboriginal customary law, it is the responsibility of Aboriginal traditional land owners to "care for country" through burning landscapes periodically. Fire is an essential tool of daily life: it aids in the hunting of macropods, in the clearing of living areas of snakes and other potentially harmful creatures (centipedes, spiders, scorpions).

In the Northern Territory, Aboriginal people own the highest proportion of the land mass of any jurisdiction, in this case 52 per cent, and it is here too that European pastoralism constitutes a very high proportion of land use. Most pastoralism in remote Australia takes place on marginal land. The Bushfires Council of the Northern Territory ignites control fires in the European pastoral areas by aerial seeding as a form of backburning to create fire breaks and to stop wildfires by reducing fuel load.

This institutional management of fire on pastoral land creates an impression for pastoralists and police that lighting of fires by individual Aboriginal people constitutes vandalism and threat to property. Aboriginal fires may not be perceived as fire management by the remote European population.

If Aboriginal people are arrested for lighting fires, they face $1,000 fines or six (6) months in jail, although there is an argument that they would face mandatory sentencing, because the offence would be categorised as a property offence under the criminal code. In the Northern Territory, mandatory sentencing applies. (A set of evidence that fits a charge under both the Bushfires Act and the Criminal Code could lead to the accused being charged twice, that is, under each Act. The Crown does not have to show intent but rather that any reasonable person would have foreseen a likelihood of injury or death to a member of the public.)

The Aboriginal Land Rights Act provides a statutory right to Aboriginal people in relation to their land to enter, occupy and use their land in accordance with Aboriginal tradition. (Although this interpretation has not been tested, it is assumed that only a traditional owner, defined according to custom, would be authorised to light a fire on a particular area of land.)

Therefore on Aboriginal land, it is assumed that the supremacy of Commonwealth law, providing this statutory customary right as it does, overrides Territory law, that is, the *Bushfires Act*, and it would be of no effect on Aboriginal land, to the extent of the inconsistency—customary landscape burning could not then constitute an offence.

If an Aboriginal person were charged with arson or property damage as a result of customary landscape burning, the defence would combine these aspects of the Australian laws, that is both Territory and Commonwealth. The Criminal Code raises three general areas of defence: authorisation, justification or excuse, and permits more than one category to be used as a defence. The defence of authorisation under the provision of the Aboriginal Land Rights Act permitting enjoyment, use and occupation of Aboriginal land, according to custom, would be available. This defence would not be applicable where a customary Aboriginal fire spreads from Aboriginal land to non-Aboriginal land, causing damage or injury.

The threat of imprisonment for lighting fires has been a powerful dissuasion for Aboriginal customary burning in all jurisdictions. Only in the Northern Territory does the supremacy of Commonwealth protection of Aboriginal custom override the local fire control statutes.

Aboriginal people in all jurisdictions, except on Aboriginal land in the Northern Territory, risk imprisonment or fines each time they undertake landscape burning. The Aboriginal determination to protect the diversity of habitats and floral and faunal species through mosaic landscape burning in these highly risky circumstances demonstrates the ongoing resistance to ecological transformation of landscapes by large scale European pastoralism, and inappropriate land use in remote Australia.

4 POSSIBILITIES FOR THE FUTURE: RESEARCH AND MANAGEMENT

Yet Aboriginal people are reasserting their cultural traditions of environmental stewardship. Peter Cooke (forthcoming: 1), the Manager of the Caring for Country Unit at the Northern Land Council, provides a succinct summary of the present situation and the future potential of reinstating traditional Aboriginal burning regimes:

> There is a growing recognition of the positive effects of traditional burning regimes but many non-Aboriginal settlers still regard Aboriginal landscape burning as anarchic pyromania. This antipathy colours Aboriginal perceptions of Government burning regulations and has led some communities to cease traditional burning, believing they may be jailed for lighting fires. The biggest factor affecting fire management on Aboriginal land have been and continue to be demographic. From late last century Aboriginal groups were progressively drawn off their lands and into Christian missions and government settlements where traditional practices were at best ignored and at worst suppressed. From the 1970s many groups were "allowed" and then assisted to return to traditional lands and establish small communities ranging in size from a few people to more than 100. Return to traditional lands has brought back traditional burning practice in those areas. However, there remain very large areas of Aboriginal land which are difficult to resettle for a variety of reasons and where problems with large destructive wildfires late in the dry season are evident. The Northern Land Council's Caring for Country Unit is committed to helping landowners address fire problems and develop sustainable resourcing for appropriate fire management through development of participatory planning processes, collaboration between Aboriginal ecological experts and non-Aboriginal scientists, utilisation of economic projects such mining, tourism and buffalo harvesting to support traditional fire management and resettlement of unpopulated areas, as well as capacity building within and between Aboriginal resource agencies which have an interest in land management. Future effective management will depend on finding an appropriate mix of Aboriginal and non-Aboriginal knowledge and technology and the resources to

sustain application of that mix.

Because of the assertion of Aboriginal people's rights to control and manage their traditional resources, and the increasing influence of the research findings in political and bureaucratic circles, Federal National conservation and national park management authorities, and some State authorities, have developed policies in the last decade for reproducing Aboriginal fire management practices in order to maintain the landscapes of the wet-dry tropics and the arid zone. In a few cases, these efforts have been carried out in collaboration with the Aboriginal traditional owners of the relevant areas.

Some of the key social and policy issues that arise from these new policy developments include the alteration to landscapes by large grazing animals, such as buffaloes and the dissonance between park management and Aboriginal responses to managing fire in such areas. New Aboriginal approaches to re-introducing Aboriginal traditional methods may be more successful. In the words of Yibarbuk, "fire must be managed, and people must be on their country to manage that fire" (Yibarbuk, 1998:6).

5 THE OFFICIAL REFERENCES TO FIRE MANAGEMENT IN PLANS OF MANAGEMENT OF NATIONAL PARKS IN THE NORTHERN TERRITORY

Two national parks in Australia are held to be models for Aboriginal involvement in protected areas: Kakadu National Park in the most northern region of the Northern Territory and the Uluru-Kata Tjuta National Park in the central desert region in the Northern Territory. Both share a number of features:

- The land was successfully claimed under the very stringent provisions of the federal act, the *Aboriginal Land Rights (Northern Territory) Act* 1976, and upon the grant of the land by the federal Minister for Aboriginal Affairs issued in the form of a statutory inalienable freehold title held by an Aboriginal Land Trust on behalf of traditional owners;
- Various parties, notably the provincial Northern Territory Government (which operates under a limited *Self-Government Act*), argued before the Aboriginal Land Commissioner that detriment would be caused to them if the land were granted to an Aboriginal Land Trust;
- As a result of the efforts of the federal Minister for Aboriginal Affairs to meet his obligation to resolve the detriment issues, arrangements was negotiated between the federal department and the representatives of the traditional owners which provide for, in each case, 99 year leases of the areas granted to the Commonwealth Government for the purposes of national parks use, Aboriginal majorities on the Boards of Management, periodic reviews, and other critical mechanisms providing opportunities for the involvement of the traditional Aboriginal owners in the management of the national parks.
- The joint management arrangements for the national parks are provided for under statute, *National Parks and Wildlife Conservation Act* 1975.

The relative success of these arrangements is reflected in the references to fire management in the Plans of Management (POM) of Kakadu National Park and Uluru-Kata Tjuta National Park.

5.1 The Kakadu National Park

The Kakadu National Park (POM) recognises explicitly the cultural dimensions of fire management:

> For many hundreds of generations, Bininj/Mungguy have used fire as an important way of managing and expressing ownership of country. Bininj/Mungguy also used fire to make it easier to travel, for communication, for defence and to clear an area of pests (Braithwaite and Roberts 1995). Fires were used to make it easier for Bininj/Mungguy to see animals when hunting, as well as flushing out other animals. Spiritual and cultural obligations were also important with fire not being lit in some places. In other places the country had to be burnt before people entered it, according to Aboriginal tradition. Fire and smoke were used to purify in many places. Bininj/Mungguy still burn country today for a number of these reasons, including using fire and smoke for rituals and purification and for hunting reasons.
>
> Since proclamation of the park, management has tried to return to using fire more traditionally. Prescribed burning, focusing particularly on the early dry season, has been done by park staff to: (a)

reduce grass fuels; (b) stop fires from spreading later in the dry season by providing barriers with less fuel between large blocks of unburnt country; and (c) protect fixed assets and sensitive habitats such as small rainforest patches. Fires have been lit from both the ground and the air in the prescribed burning program. This program has had more resources since 1991 so more attention has been given to managing remote areas and managing habitats. Bininj/Mungguy residents still burn country, particularly around outstations areas and areas used for hunting and gathering purposes, especially floodplains.

The continuance of traditional Aboriginal fire management in parallel with park management efforts is particularly noteworthy because of the high standard of research and documentation on these efforts and ready acceptance of the importance of traditional knowledge of fire. This is openly acknowledged in the POM and sets the high water mark for official policy, planning and management in Australia:

> Information about how Bininj/Mungguy managed the country using fire in the past has been documented in detail by researchers (e.g. Lewis 1989;Lucas Lucas 1993; Braithwaite and Roberts 1995; Russell-Smith et al. 1997a; Bridgewater and Russell-Smith 1997). Extensive research, resulting in a very large body of scientific knowledge, has been carried out on fire ecology and the impact of fire regimes on various habitats, ecosystems and animals (e.g. Hoare et al. 1980; Braithwaite 1987; Bowman 1994; Bowman and Panton 1993; Lowe 1995; Russell-Smith 1985a; Russell-Smith et al. 1993; Anderson 1996; amongst many others). The fire history of the park since 1980 is known in detail through the analysis of satellite imagery (Du Rieu and Russell-Smith 1996). An overview of fire management in Kakadu is provided in Russell-Smith 1995.[22] [23]

This large body of research includes fine-grained analysis of traditional fire management regimes and the impact of European settlement on these Aboriginal landscapes, and the Kakadu POM acknowledges this in detail:

> Fire is used in a way that is finely attuned to the climate, vegetation and fauna. Habitats have been managed in different ways according to the resources available within them. Hunting areas, particularly floodplains, creek lines and adjoining woodlands, were burnt throughout the year, with only small areas being burnt at any one time. Fires were directed on to areas that had been burnt before or other barriers and usually went out within a day or two. In the early, cool part of the dry season, particularly in *yekke* and *wurrgeng* (typically May through July), a lot of preparatory burning was done as part of *arri wurlhke*, systematically burning rank grasses, i.e. 'cleaning the country'. During *gurrung*, the very hot, dry time of year at the end of the dry season (usually August though October), when fires are often intense and difficult to control, burning was done particularly carefully. Burning the country regularly and during the early dry season also meant that many plants used for food, such as yams, were protected.
>
> When *Balanda/Mam* occupied the land the *Bininj/Mungguy* population was reduced and redistributed. Because of this, traditional Aboriginal ways of burning, which needed a lot of people who were able to move around easily, were greatly disrupted. As a result, the landscape lost the fine mosaic of burnt and unburnt patches, which had previously protected the area from damaging, hot fires. Extensive burns in the late dry season became more common. When pastoral activities developed, different ways of burning were introduced. Fire was used to improve pasture productivity and to clear undergrowth so stock could be mustered. Fires were often lit late in the dry season, resulting in extensive hot fires.[24]

The discusion of fire management in the POM is the most sophisticated of all the national park POMs surveyed in this paper, because of the strong research tradition in this region, and some of the key features are set out below to provide a point of comparison for the subsequent discussion of references to fire management in other National Park POMs (Caring for Country, Managing the Natural Heritage of the Park, A Plan of Management in Respect of Kakadu National Park, Kakadu National Park Plan of Management 1997, Commonwealth of Australia, 1997: 4-7).

> The aims in relation to fire management are to:
>
> - promote traditional Aboriginal ways of burning within the park;
> - protect life and property within and adjacent to the park;
> - restrict fire from spreading so that it doesn't enter or leave the park; and

- maintain biodiversity through effective fire management of species and habitats.

The POM also elaborates the issues in relation to these aims, noting the importance of parallel Aboriginal traditions to the task of fire management:

> Being prepared, aware and safe: Fire has to be managed effectively throughout the park in order to protect lives and property. Managing fire properly includes having an effective program to reduce fuel and break up its continuity across the landscape, as well as educating residents and visitors about using fire appropriately.
>
> Restricting fires from entering or leaving the park: It is very important in managing fires to make sure that the boundaries of the park are well managed so that unwanted fires, particularly those burning late in the dry season, cannot enter or leave the park. Historically, most fires that enter the park have been on the eastern margin, fanned by south-easterly winds. On the other hand, fires leaving the park tend to be on the western side. There are also a number of lease areas within the park, e.g. Jabiru. Managing boundaries effectively needs close liaison with neighbours and regional organisations (e.g. the Northern Land Council, the Bushfires Council of the Northern Territory and the Northern Territory Fire Service), detailed planning and being prepared, and carefully and thoroughly doing fuel reduction programs.
>
> Managing habitats: A number of communities and species are recognised as being sensitive to fire, and are therefore particularly threatened by frequent, intense fires. These include all rainforest communities, slow-growing heath communities of the sandstone plateau and escarpment, Cypress pine thickets (Callitris intratropica), bamboo thickets (Bambusa arnhemica), and mature floodplain paperbark (Melaleuca spp.) forests and woodlands.
>
> Fuel needs to be reduced strategically as part of managing habitats in all the major landform systems of the park: the floodplains, lowlands, and escarpment and plateau. In recent years fuels have built up noticeably on lowland riverine floodplains, because buffalo have been removed. In order to try to stop fires spreading off and onto floodplains later in the season, greater effort is required to systematically reduce fuel on floodplain upland margins as these dry out. A major issue in managing habitats in the lowland woodlands is that a fine-scale mosaic of patches that covers a range of fire histories should be developed. Currently there are few areas that remain unburnt for more than a few years. Current ways of managing fire-sensitive sandstone plateau habitats are to cut down on frequent, extensive late dry season fires by strategically reducing fuel that is concentrated along major water courses.
>
> Involving Bininj/Mungguy: Traditional owners often say they are concerned about fire management of their country. They sometimes feel left out of planning and are concerned that particular country, especially important hunting areas such as floodplains, are not being burnt in traditional ways. It is important that Bininj/Mungguy are able to maintain their traditional fire management skills and contribute to the park's fire management program. Using fire is an important part of Bininj/Mungguy culture.
>
> Research and monitoring: Further fire management research and monitoring programs need to be developed to assess how effective the fire management program is. Extensive fire research and monitoring programs have been done in the park. Long-term fire research field programs at the Munmarlary and Kapalga study sites have now effectively stopped, and are currently being assessed. Long-term monitoring of how much and in what seasons burning happens in Kakadu has been undertaken from 1980 using satellite imagery. These data indicate that: (a) since the park has been established, the pattern of fires has changed in a major way from one dominated by extensive late dry season fires to one dominated currently by small fires in the early dry season; (b) large fires have been mostly prevented from entering the park, especially on the eastern boundary; and (c) substantial management problems remain, including fine-scale habitat management of lowland woodland and floodplain habitats. Permanent plots have also been established in all management districts of the park to assist park staff to monitor the ecological effects of their fire management practices.

5.2 The Uluru-Kata Tjuta National Park

In contrast, the Uluru-Kata Tjuta National Park Plan of Management (POM) reflects the relative absence of research in this arid zone. The aims and issues set out in the POM are thus rather more succinct than in the Kakadu National Park POM:

Issues:

- if fire-sensitive plant and animal cummunities are to be protected they should be mapped clearly and specific prescriptions for protection should be formulated;
- fire management in the Park cannot be undertaken in isolation from the greater region; wildfires from beyond the Park's boundaries have the capacity to seriously damage ecosystems in the Park.

Aims:

- to maintain traditional Anangu burning practices and promote their integration with scientific knowledge, to protect and enhance the Park's biodiversity;
- to protect life, property and culturally significant sites and mitigate the effects of wildfire;
- to maintain community education and interpretation programs dealing with the role of fire in the Park;
- to maintain a research and monitoring program and operate within a regional context and to help neighbours suppress wildfires when resources are available. (Uluru - Kata Tjuta National Park Draft Plan of Management, February 1999: 68-71.)

The Park is governed by a Board which has a majority of Indigenous traditional owners. (Uluru - Kata Tjuta National Park Draft Plan of Management, February 1999:70-71) The Park Board and Management nevertheless have developed a strong collaborative relationship with the traditional Aboriginal owners, referred to as the *Ngurraritja* in the local languages. Topsy Tjulyata has attested to the satisfaction of the local indigenous people with the collaborative management work:

> We're thinking together about this work in the Park and the Anangu and ranger workers. Traditional owners and Park leaders together discussed and made rules and they explain how the non-Anangu rangers can work effectively through Anangu and through the community. Others go on the Liru and Kuniya Walks and others again work together making windbreaks for the cold weather and lighting fires to protect ancestral country from burning. And they are really happy doing these things. [translation]

The Park joint management arrangement represents a successful and innovative administrative adjustment to Aboriginal land ownership and traditions in this important arid zone conservation area.

> Fire management is a fundamental management practice in the Park and a clear example of the adaptive management process operating successfully within the joint management framework. (Uluru - Kata Tjuta National Park Draft Plan of Management, February 1999: 68-71.)

The Plan of Management states an approach to fire management in an area of cross-cultural landscape management of at least equal complexity to the circumstances of Kakadu National Park managers, based on this collaborative approach:

> The Indigenous communities will continue to be involved in all aspects of fire management and traditional fire-management knowledge will continue to be documented and promoted as appropriate.
>
> An evaluation of the fire-management strategy is being commissioned by the park, and the strategy is to be updated in consultation with the Anangu.

The major issues are stated in the following way:

- Protecting fire sensitive plant and animal communities, and
- Fire management is not being undertaken in isolation from the surrounding region as wildfires from beyond the park have the capacity to seriously damage the ecosystem.

There is a paucity of research in relation to fire management in the semi-arid and arid zones of Australia. Bowman has summarised the literature finding that there is an "impoverished palaeo-ecological record" (1998:400). The Commonwealth Scientific and Industrial Research Organisation (CSIRO) developed a fire-management strategy (Saxon 1984) to mitigate the destructive effects of wildfires in this arid region where spinifex colonisation of all habitats creates a highly flammable fuel load. The Park has commissioned an evaluation of the fire-management strategy. The Plan of Management cites the "displacement" of Anangu, the indigenous people of the land, and the consequent loss of traditional burning regimes "over vast areas", as the major contributing factor to loss of habitat diversity and the extraordinarily high loss of biodiversity in this region. Other factors include the presence of large populations of feral exotic predators (cats, foxes, dogs) and feral populations that compete for habitat dominance (rabbits):

> The spatial and temporal mosaic of Anangu fires has created 'patches' in the landscape. The regime was maintained for thousands of years and had the effect of inhibiting the spread of wildfires.
>
> Before Europeans introduced livestock, fire was used extensively by Anangu in Central Australia. Anangu deliberately intervened with fire and developed it as a technology for ecosystem manipulation (Jones 1969, Hallam 1975). They did this for a number of reasons, such as hunting and the encouragement of 'bush tucker' vegetation and green feed for animals. Burning was an integral part of life and fundamental to looking after country. Anangu typically burnt as they travelled the country; most movement, and burning, occurred in the cooler months or following large rains.
>
> 'Areas were managed through the use or non-use of fire according to landform and vegetation as well as criteria which derive from the Tjukurpa' (Baker et al. 1993).
>
> After the arrival of European people in Central Australia the displacement of Anangu resulted in a loss of traditional burning regimes over vast areas. As a consequence, the pattern changed from the previous mosaic of patch burns to extensive areas of country carrying increasing fuel loads associated with unburnt vegetation. The inevitable result was huge wildfires following periods of above-average rainfall. (Uluru - Kata Tjuta National Park Draft Plan of Management, February 1999: 68-71.)

The loss of biodiversity in the arid zones of Australia proceeds at an alarmingly high rate. In Central Australia, over 40 per cent of mammal species have become extinct since European settlement. The Uluru Kata Tjuta POM attributes this loss, at least in part, to the loss of habitat diversity associated with the earlier mosaic patterning created by Aboriginal traditional burning. The Plan refers to the catastrophic results of the demise of this tradition with the removal of Aboriginal people to settlements in the 1940s and 1950s: "Serious wildfires in 1976 burnt about 76% of the Park. Subsequently, CSIRO developed a fire-management strategy (Saxon 1984) to mitigate the destructive effects of wildfires."

The Plan sets out some of the objectives of the fire-management regime in terms of biodiversity conservation, integrating "aspects of traditional Anangu burning practices with a scientifically based approach" (Uluru - Kata Tjuta National Park Draft Plan of Management, February 1999: 68-71):

> The Uluru fauna survey also resulted in a number of recommendations that were incorporated in the fire-management program:
>
> - that the majority of the standing mulga and much of the regenerating 1976 mulga be protected form fire;
> - that the majority of 1976-aged spinifex be protected form fire, at least until surveys to search for rare species are concluded;
> - that mallee-spinifex areas be protected from fire until they have been surveyed for rare species;
> - that surveys of these habitats be carried out to assess and map their habitat quality for wildfire and that recommendations arising from the research be formally written into the fire-management strategy;
> - that, notwithstanding the foregoing the patch-burn strategy be vigorously pursued to promote landscape and faunal diversity (Reid et al. 1993);
>
> Integral to the strategy has been the use of satellite data and a geographic information system in the development of fire history maps for recording both management and wildfire burns and in planning future burning.
>
> Fire management is a fundamental management practice in the Park and a clear example of the adaptive management process operating successfully within the joint management framework. (Uluru - Kata Tjuta National Park Draft Plan of Management, February 1999: 68-71.)

5.3 Nitmiluk National Park

The Nitmiluk National Park arrangements differ from Kakadu and Uluru Kata-Tjuta in one significant respect: the managing authority under the joint Agreement is the Northern Territory Parks and Wildlife

Commission, and not Commonwealth Parks Australia. In most other respects, the arrangements are substantially similar: the land was claimed under the Aboriginal Land Rights Act and negotiations led by the Northern Land Council on behalf of the traditional owners resulted in joint management arrangements under a lease to the Northern Territory government with provision for an Aboriginal majority on the Board and the involvement of traditional owners in the management of the Park.

The Nitmiluk National Park Plan of Management (1993) acknowledges that Aboriginal traditional owners used fire, or wurrk, as a tool for habitat management and that much fire use knowledge is retained by traditional owners today. The plan provides for a Fire Management Plan incorporating an annual Fire Control Program to be updated annually. It is prepared in consultation with the traditional owners and the Bushfires Council and the adjacent landowners. Unlike the Commonwealth jointly managed Parks discussed above, the Nitmiluk POM fire management program objectives do not explicitly refer to either biodiversity conservation or the role of traditional owners. The objectives are stated in this way:

- to maintain appropriate fire regimes and effective fire breaks;
- to protect Park assets;
- to provide adequate safety.

The absence of such critical references is in line with the frontier culture of the Northern Territory government and administration. The problem of biodiversity conservation is referred to at page 30 of the POM in a circumspect way:

> Failure to maintain and/or develop appropriate practices could result in significant damage to the natural resources of the Park.

The involvement of traditional owners is referred to in Management guidelines:

> Management guidelines in consultation with traditional owners include
> - recognising importance of fire
> - research and documentation
> - identify zones for specific treatment
> - identify priority hazard reduction
> - detailing fire fighting resources
> - co-operative programs
> - take account of frequency of lightning strikes
> - inform visitors of fire management practices through interpretation.

5.4 Other "National Parks" In The Northern Territory

The lease and administration arrangements for the Gurig National Park, on the Aboriginal Land Trust on the Coburg Peninsula, were negotiated after the handover of the Kakadu and Uluru Kata-Tjuta National Park but prior to those for the Nitmiluk National Park.

It is unlike Kakadu, Uluru-Kata-Tjuta and Nitmiluk in its management arrangements in that the traditional owners do not hold a majority of positions on the Board. The Board of Gurig National Park has 8 members appointed by the Minister, 4 of whom shall be nominated by the Northern Land Council. The traditional owners are not involved in joint management arrangements here, as are the traditional owners of the previously discussed national parks. The traditional groups associated with this area were unable to reside permanently on the Peninsula, having been drawn to mission settlements on nearby islands and further south in Arnhem Land in the frontier period in the early decades of this century. Following the successful land claim settlement, the descendants returned to re-establish their homelands. The POM recognises their continuing traditional knowledge of the area and their importance to sustaining the environmental values of the Park area, citing the traditional Aboriginal calendar showing fire burning times (1987: 11):

> With the return of traditional owners ... in 1982 attempts are now being made to develop a fire control system which effectively integrates Aboriginal burning practices with systematic hazard reduction and

wildfire control burning… (1987: 58).

The coastline is a highly valued nesting area for four marine turtle species, at least one of which is endangered. The Plan of Management (1987: 57) cites the then attempts to establish a fire regime "which includes burning by traditional owners and controlled burning by the Conservation Commission." This odd phrasing refers to the documentation of a plan and the authorisation of Aboriginal burning by such a plan rather than the absence of traditional fire use. The Conservation Commission controlled burns would have been introduced as an extension of its existing program associated with forestry activities on the eastern end of the Peninsula.

Points presented in the POM include the importance fire has played in the ecology of the area including intensive wild fires "before the presence of man". Current indigenous use of fire is described and wildfires resulting from the removal of traditional owners is referred to in this way:

> Major fires have and continue to occur … while traditional owners have been away from their land or have been leading a more sedentary life (1987: 58).

The Parks and Wildlife Commission was previously the Forestry and Conservation Commission and since 1967 the staff at Coburg Peninsula have undertaken controlled burning by aerial seeding to protect the Territory Forestry assets on a 2 to 3 year rotational basis supplemented by on-ground burning near visitor areas.

The Park has a far smaller visitation levels because of its extreme remoteness.

Other so-called "national parks" in the Northern Territory are governed solely by the Parks and Wildlife Commission of the Northern Territory and make no pretense whatever to the involvement of the traditional owners. The Litchfield National Park, for instance, just over an hour's drive from the administrative centre of Darwin, has very high tourist visitation rates, and no involvement of Aboriginal traditional owners.

The Plan of Management (Parks and Wildlife Commission of the Northern Territory, 1992: 55) provides only this bare statement:

> The Park's Crocodile Management Plan, Fire Management Plan and Emergency Response Plan will be reviewed and updated annually.
>
> All emergency, first aid, fire control and communications equipment will be maintained to a high standard in a 'ready to use' condition.

The Watarrka National Park in Central Australia (Watarrka National Park Plan of Management 1989: 57) similarly manages fire with little reference to the scientific knowledge and documentation of traditional ecological knowledge:

> A Fire management Strategy has been prepared and is reviewed annually by the Fire Management Committee. Records will be kept and research continued to be used in the preparation of a Fire Action Plan, prediction of fire behaviour, direction of fire control operations and research projects. The preparation of a Fire Action Plan, in conjunction with the Local management Committee, is listed as a high priority in the Management Plan.
>
> In the control and suppression of fires preference will be given, as far as practicable, to those measures judged by the Local management committee and specialists units within the conservation Commission as having the least environmental impact and disturbance … Bans controls or other regulations and restrictions governing the lighting and use of fires as enforced by the Bushfires Council or required by law, will apply to traditional owners, visitors and, as far as possible, management fires on the Park.

5.5 Fire Management In National Parks In Other Jurisdictions

5.5.1 South Australia: The Witjira National Park Management Plan

In the northern region of South Australia, in a distinctive arid zone, the Witjira National Park, is managed by the National Parks and Wildlife Service of the State Department of Environment and Natural Resources.

The Witjira National Park Management Plan (North Region, South Australia, Compiled by National Parks and Wildlife Service, Department of Environment and Natural Resources, October 1995: 29-30; 4.6.4 Fire.) maintains that, "because the risk to life and property is very low, suppression of unscheduled fires is not a significant concern in management of the Park". The fire management is based on available scientific research and minimal documentation of traditional ecological knowledge:

> Because of the sparse vegetation, bushfires are not a feature of the stony tableland and downs country of the Park. Occasionally fires, such as from lightning strikes, must be expected in the sandy plains vegetation fringing the mound springs, floodplains and dunefields. These will only be extensive after relatively good seasons when ephemeral and grass fuels are heavy and cured. Under suitable conditions, parts of the Finke floodplain where coolabah regrowth is dense may be vulnerable to intense fires. The areas are small in extent.

The concern of the fire management plan is for the residents of the Park area as a public safety issue and for the built environment in terms of property value:

> Greater risk to life and property is posed by the potential for fires to be ignited or spread in buildings or fuel storage areas such as at Mt Dare and, potentially, at living areas in the Park. This risk is minimised by ensuring such facilities are built and maintained to appropriate specifications. These matters are covered in lease conditions.

"Little is known of former Aboriginal burning practices in the Park" (1995: 30), the Plan frankly admits, and further recounts the minimal oral history collected from traditional owners:

> Lower Southern Arrernte and Wangkangurru people recall that certain areas would be burned, such as creek and spring fringes at Dalhousie, but they have engaged in little burning since the pastoral era began.
>
> Irrwanyere elders have commented that reeds along outflow channels at Dalhousie Springs and some other vegetation is now far denser than earlier this century and that changes in fire regime may be one reason. On the other hand, a vegetation survey at the springs in 1985 found that bulrushes and reeds were nowhere as high as they were described as being in the 1870s (Mollemans in: Ziedler and Ponder 1989).

The Plan acknowledges past Aboriginal burning practices but states that little is known about these practices. The vegetation has undergone tremendous change and this is in part from stock and feral animals and the disruptions to Aboriginal land use and management. The Plan proposes the implementation of:

> Research into Aboriginal burning practices
> Monitoring and suppression of unwanted fires
> Measures to minimise risk of fires.

The Plan proposes to:

- research Aboriginal burning practices in the Park that may have been used to manage vegetation and habitat.
- monitor and map unscheduled fires. Take suppression action that is feasible and warranted if risk is posed to life, facilities or historic structures.
- Ensure that developments in the Park incorporate measures to minimise the risk of fires igniting and spreading.

5.5.2 The Australian Capital Territory: Namadjgi National Park

The Park Manager (pers. comm.) explains the absence of indigenous involvement in fire management in the Australian Capital Territory and Alp region in this way:

> Indigenous communities have not been consulted regarding fire management and may have lost their traditional knowledge of fire use in managing the land. This is not to say that they should not be consulted. The Park Management Plan was written in 1986 and is in need of being renewed but this process is being delayed while Native Title Claims are under consideration (pers. Comm. Park Manager).

There is a fire management document for the entire area of the Australian Capital Territory region and the Alps region, including the Kosciuscko National Park.

This situation is to be expected given the demise of the Ngunawal population in colonial times, following the measles, influenza and smallpox epidemics which followed the European settlers into the region. The descendants of the Ngunawal have made a claim of native title over part of the region and seek the protection of Aboriginal sites.

5.5.3 Victoria: Grampians National Park (Gariwerd)

In the Draft Plan of Management of the Grampians National Park (Gariwerd) 1998, fire management is listed as priority strategy for management but no mention is made of any Indigenous consultation on this subject. There is reference to historical fire regimes experienced and the co-operation of the Country Fire Authority and private landholders in minimising the impact of fires. (1998: 23)

> Much of the Park has been subjected to both planned and unplanned fires at some time over the last 60 years. There are also some long-unburnt areas totalling approximately 34 115 ha in small areas scattered through central and western sections of the Park.

Fire is a major factor in the ecology of the Grampians vegetation and its associated fauna. Many of the plant communities have evolved with fire, but some species could be threatened by fires which are too frequent, or conversely by long-term fire exclusion. The management of fire therefore presents a challenge, particularly in regard to establishing appropriate fire regimes in an area of such diverse and closely juxtaposed vegetation communities. (1998:7)

Ecologically-based fire management prescriptions are being developed for the Park, based on FCs and Key Fire Response Species (Tolhurst 1996; See Draft Plan of Management, 1998: Section 6.1). This work depends on the completion of FC mapping for the Park, due by December 1998.

Threats to the vegetation of the Grampians include weed invasion, over-grazing by native and non-native herbivores, illegal flower picking, poorly managed fire regimes, recreation activities, road and track maintenance and construction, and Cinnamon Fungus spread. (1998: 17-18: Section 5.3 Vegetation).

The Plan speaks of the '… continuing strong association by Aboriginal people with the area' (1998: 6). But their involvement appears to be limited to the study of archaeological collections, the management and interpretation of rock art sites and the management of the Brambuk Living Cultural Centre which focuses on Aboriginal cultural heritage (1998: 21, 32; see Section 6. Park Protection, Section 6.1 Fire Management, 1998.23-24).

The National Parks Act requires the Director of National Parks to ensure that appropriate and sufficient measures are taken to protect Parks and people from injury by fire. Fire management within the Grampians National park is controlled by three levels of fire planning: the Code of Practice for Fire Management on Public Lands (CNR 1995a); the Horsham Region Fire Protection Plan (DCE 1989); and the forthcoming Grampians National Park - Black Range State Park Fire Management Plan.

Fire has been a common occurrence, and large areas of the Park were burnt in 1985, 1988, 1989, 1990, 1992 and 1994. Co-operation with the Country Fire Authority and private landholders for the common purpose of fire management within the park and on adjacent land has minimised the impact of these fires.

The effect of fire on flora and fauna is recognised as an important consideration for the management of the Park. It plays an essential role in the ecology of various species and communities that have evolved under particular fire regimes.

In the management of species and communities reference is made to the historical fire regimes experienced. Relatively good data is available on fire occurrences, type and extent within the Park. This data has been incorporated into a Geographic Information System (GIS) capable of assessing the historical fire regimes experienced.

The Draft Plan would require that fire management within the Park encompass not only protection of life and property from the impact of wildfires, but also the ecological management of species and communities.

The Aims of the Management Plan would be to:

- Protect human life and property and park values from injury by fire.
- Minimise the adverse effect of fire and fire suppression methods on park values.
- Maintain fire regimes appropriate to the conservation of flora and fauna.

The Management Strategies in relation to fire management propose to:

- Implement fire management in accordance with the requirements of the Regional Fire Protection Plan and consistent with the Code of Practice for Fire Management on Public Lands.
- Complete and implement the Grampians National Park - Black Range State Park Fire Management Plan including:
  - Completion of Floristic Community mapping;
  - Continual updating of fire history maps in GIS;
  - Development of a GIS based decision support process for fire planning;
- Identification and mapping of fuel loads, to assist in fire management and prescribed burning planning;
- Ongoing research and monitoring within vegetation communities to identify, and improve knowledge of, indicator species and their fire prescriptions.
- Encourage scientific research into the impact of fire on the flora and fauna of the Park area.
- Through training, develop the skills and knowledge of decision-making processes of Park management staff in fire management and suppression, fuel reduction burning and GIS applications.
- Assess the operational significance of existing fire dams and helipads with a view to enhancing the efficiency of operations, in liaison with Forests Service.
- Ensure that the use of bulldozers for fire suppression or fuel reduction burning is subject to careful planning and continuous supervision.
- Undertake appropriate rehabilitation and revegetation works following fire suppression activities.
- Do not use machinery and fire retardants for fire suppression within Reference Areas other than in extreme circumstances.
- Maintain liaison with adjoining communities, landholders and local Country Fire Authority brigades on issues relating to fire management.
- Increase community awareness of fire management programs with the Park, and integrate these into information services provided to visitors (section 7.1.2).
- Develop and ensure application of a guideline on preferred methods for suppression of wildfires in the Park.

The Cultural Values of the Grampians National Park are referred to in the Draft Plan as “outstanding” and include:

- 80% of known Aboriginal art sites in Victoria;
- a continuing strong association by Aboriginal people with the area;
- a European history rich in diversity, content and interest.

The section of the Draft Plan that documents cultural values (1998: 21, Section 5.6 Cultural Heritage) notes, without any reference to archaeological or historical literature, that

> Aboriginal people of Western Victoria have a long association with the Grampians Ranges. The Ranges were central to the dreaming of the Jardwadjali and Djap Wurrung people.

The Plan refers to the involvement of the local indigenous people in the interpretation of cultural values through their award-winning and culturally significant Brambuk Living Cultural Centre in the Park near

Halls Gap, and through the reestablishment of the Tandurrum Ceremony. According to the Draft Plan, at the Centre and the Ceremony, knowledge of past and present culture is being passed on, although it also notes:

> Much knowledge of earlier Aboriginal culture was lost during settlement, and what is now known has been gained from descendants through oral history, historical documents and archaeological research.
>
> The long and continuing Aboriginal association with the Grampians is a major interpretation of the Park. At present four rock art sites are promoted and have interpretation.
>
> In 1990 the traditional Aboriginal names of 76 places in and around the Grampians were proposed in recognition of the long history of the Aboriginal people in western Victoria. The traditional Aboriginal names for rock art sites which are open to the public are in use, as are dual names for some features in the Park.

5.5.4 New South Wales: Mutawintji National Park and Historical Site and Coturaundee Nature Reserve

The Plan of Management states, "There is no evidence that fire has played a significant role in development of vegetation in Mootwingee National Park, Mootwingee Historic Site or Coturaundee Nature Reserve" (1989: 13). The Plan does admit however that, "The potential does exist for a major fire to occur after good rains lead to rapid growth. If this does not occur it could have a major impact on vegetation communities" (1989: 13).

The Policies set out in the POM require fire control to "maintain conditions so that the natural eco will be strengthened and maintained", to "preserve rare and threatened species and plant communities", and to "reduce the risk of fire damaging service developments, natural ecosystems and neighbouring property".

A traditional Aboriginal calendar is presented in diagram form (1989: 11, Figure 2.2.1) as an indication that some research on Aboriginal knowledge of the environment is available. However, liaison with the Mutawintji Aboriginal Land Council and the Western Region Aboriginal Land Council is mentioned in relation to the management of Aboriginal sites only (1989: 17).

One of the objectives of management is '…to allow natural processes to continue unhindered as far as possible' (1989: 8). Preparation of a fire plan is listed as a low priority (1989:25). The actions outlined in the plan prior to fire prescriptions being prepared cover:

- the documentation of the area's fire history,
- fuel hazard reduction programmes not being initiated except in the vicinity of developments at risk
- boundary management trails being maintained and extended where practical
- tanks and dams being kept in good condition and access tracks maintained. (1989: 13, 14).

Wood fuel would be supplied for barbeques until gas barbeques are installed and this action is also listed as a low priority (1989: 21, 25).

Actions required under the POM are set out as follows:

> Fire prescriptions will be prepared. Until that time:
>
> - The fire history of the area will be documented as fully as possible.
> - Fuel hazard reduction programmes will not be initiated except in the vicinity of developments at risk.
> - Boundary management trails will be maintained and extended where practical.
> - New Tank, Mt. Wright Tank, Two Mile Tank, the house tank, the dam in the Historic Site and Amphitheatre Well will be kept in good condition for fire fighting and access tracks to these water bodies maintained.

6 CONCLUSIONS

This assessment of the integration of Aboriginal fire management traditions into the management of national parks shows the marked relevance of Aboriginal knowledge of ecological systems and the use of fire to the challenge of managing vast regions of the Reserve Areas and the 15 per cent of the Australian land mass owned by Aboriginal people.

Kakadu, Uluru-Kata Tjuta, Nitmiluk, Gurig are all jointly managed by Aboriginal and conservation agencies with both Aboriginal and scientific fire management regimes. Their Plans of Management have the stated intention of promoting traditional Aboriginal ways of burning within the park areas, amongst other things.

A key finding in this survey is the importance of research by scientists who recognise the significance of customary Aboriginal fire use and management and the relevance of their own work to sustaining those traditions. Scientific research conducted in collaboration with traditional Aboriginal owners in the Northern Tropical savannas has played a key role in the joint management regimes in National Parks where customary Aboriginal landscape burning is promoted to conserve biodiversity. In arid central Australia, where less scientific research has been conducted, Aboriginal landscape burning is promoted and research continues.

It should be self-evident that access to traditional ecological knowledge for the purposes of biodiversity conservation and landscape planning and management is only possible where social scientists and scientists have documented such knowledge in sufficient detail to ensure its applicability where mosaic landscapes are being replicated and to ensure sound collaboration where customary burning is encouraged. The recognition and encouragement of customary Aboriginal landscape burning in several national parks are the result research and collaboration by Aboriginal land owners, land council and park management staff, scientists and social scientists.

Scientists have a role to play in the social context of sound land management practices by providing sound, relevant research to land managers, in particular, to the Aboriginal land owners whose land is used for national park or conservation purposes. The recognition of traditional ecological knowledge, further collaboration with land owners, both Aboriginal and settler, and continuing contributions to policy and planning in this highly contested field are essential elements of their role.

The Plans and Draft Plans of Management of other National Parks surveyed have the stated and primary aims of protecting "park assets", life and property by using fire control strategies. Except where it is demonstrably the case that wildfire is not a threat to park values, the phrase, "park assets", used in this way, implies the exclusion of the environmental and cultural values such as arise from the practice of replicating or encouraging customary Aboriginal burning, from the category of "park assets". The term "the built environment", a standard term in heritage legislation, is the more appropriate one to use if that is what is being referred to. Otherwise, if the environmental values of the parks are being referred to as assets to be protected by fire controls, it seems likely that the lessons of the Yellowstone National Park wildfires of 1994 have not been learnt.

It seems that, in most of these parks, there remains a strong cultural attitude to distinctive Australian fire conditions as amenable to the fire controls adopted traditionally by state forestry agencies. In these documents, there is no policy arrangement for the Aboriginal traditional owners to be involved as Board Members or in daily management. Nor do these Plans of Management explicitly permit Aboriginal customary landscape burning. The Plans may be read as complying with bushfires legislation, making no exception for Aboriginal customary fire use and management. Most aim to research fire impacts, but confine their stated objectives to fire control and management.

In these parks, it is also the case that there is insufficient scientific understanding of fire impacts and Aboriginal landscape management in these areas to replicate ancient systems. There has been a lack of research into these issues and some of the park Plans of Management aim to carry out research. Whether further research finds that replication or encouragement of mosaic landscape burning with cool fires is appropriate is a question of some significance for the future control of wildfires.

The political demand for suppression of the Aboriginal engagement with landscapes from pastoralists and other non-Aboriginal land users is in stark contrast to the successful outcomes from Aboriginal and scientific collaboration in fire management in highly valuable heritage and tourism areas.

This dissonance points to several problems: The first of these is the segregation from the surrounding landscapes of national parks managed by plural, parallel traditions, that is, the collaboration of traditional Aboriginal and modern western management systems. Habitat loss in the surrounding landscapes will continue because mosaic burning is suppressed and wildfires cause extensive damage to floral and faunal populations, leading in some areas, to high mammal and plant extinction rates.

On Aboriginal land, especially in northern Australia where the colonial and postcolonial impact has so far been lesser than in the more southern regions, high biodiversity values are being maintained wherever Aboriginal links with land are maintained by a regular presence and the practice of customary landscape burning. Aboriginal leaders acknowledge that their vast knowledge systems are at risk of not being transmitted to younger generations.

Even within large tracts of Aboriginal land, there remains the problem of the lack of an Aboriginal presence in the less accessible areas at some distance from the administrative settlements. In these areas, wildfires have been reported, and long term goals of repopulating these areas may be implemented after detrimental impacts on these landscapes and their biota has been caused. Wildfires in the escarpment of western Arnhem Land in early September have been reported along with the fear of severe impacts. These wildfires spread into the Kakadu National Park on its eastern border and, even though traditional owners had visited these areas in the Dry season and carried out traditional burning, the spread of wildfires has raised the urgency of collaboration with traditional owners of these areas to implement long term conservation strategies for fire management.

Other issues arising from these new developments include the dissonance between Aboriginal and park administration responses to fire management in such areas, and the alteration of landscapes by large grazing animals, such as buffaloes. Aboriginal approaches to re-introducing Aboriginal traditional methods may be more successful, if land councils and other agencies are able to continue to support their attempts to return to their homelands to reside, either permanently or seasonally. Yibarbuk (1998) has expressed the view that "fire must be managed, and people must be on their country to manage that fire". The strategy of re-occupying homelands will require, in many cases, the supplementary support of collaborative conservation strategies where the accumulated fuel loads and lack of traditional fire management in the recent past has resulted in the risk of severe wildfires.

This segregation of areas devoted to conservation of biodiversity from rangelands devoted, in large part, to unsustainable pastoralism, is founded in the frontier culture of European land transformation based on the elimination of Aboriginal relationships with land.

Multiple land use – that is, conservation and commercial land use combined in sustainable ways, based on the principles of biosphere reserves – may provide a solution to this dilemma. The potential for such a strategy will depend on research and experimentation in those areas where land owners permit the efforts of scientists and land managers to conduct trials for maintaining the mosaic of habitats preserved by fire management techniques derived form ancient Aboriginal practices. Aboriginal land owners have demonstrated a willingness and enthusiasm for such research and experimentation, investing in these efforts, despite their poverty and disadvantage, and showing a high level of commitment to collaborative efforts. The challenge is now for the research institutions to move beyond the segregated Aboriginal and conservation zones to the savannas and arid zones where Euro-Australian land owners are using natural resources unsustainably.

There is a further challenge in the requirement to change the administrative and legal regimes that limit Aboriginal customary landscape burning and which institutionalise the fire management on non-indigenous lands in central government agencies.

The recognition of indigenous or traditional ecological knowledge (TEK) systems in Australia, particularly in relation fire management in the cause of biodiversity conservation, is not a trivial matter. The exhortation from some in the scientific disciplines to dismiss TEK on the grounds that it is not scientifically based is a non sequitur. As Bowman and Head point out, the paleoecological record cannot resolve the issues of the impact of fire on biodiversity in prehistoric times, and neither can speculation on previous Australian environments resolve the issue of how we manage Australian landscapes today.

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[1] The ancient Greeks thought this island continent must exist, and mapped it as a theoretical hypothesis. Spanish, Portuguese and Dutch sailors from the imperial centres of Europe explored and mapped parts of the coastline before Captain James Cook claimed the eastern half of the continent on the basis of 'first discovery and possession', by such symbolic acts as hoisting a flag in several places along the east coast and finally at the place he called Possession Island in the Torres Strait, off the north eastern coast. See J, Allen (1993), "A community of culture: the people and prehistory of the Pacific," in M Sprigges et al (eds), Occasional Papers in Prehistory, No 21, ISBN 0731512987, Australian National University, Canberra.

[2] See Chappell, J, 1991, White, ME, 1986. The Greening of Gondwana, Reed Books, Chatswood, NSW, White, ME, 1994. After The Greening: The Browning of Australia, Kangaroo Press, Kenthurst, NSW; Smith (1995) summarises the debates about fire, climate and evolution in the following way:

> Pyne (1991:16) suggests the scleroforest revolution concluded between 38 000 and 26 000 years ago as the scleromorphs, led by Casuarina, completed their abrupt expulsion of the rainforest. Subsequently another revolution broke out between 20 000 and 7 500 years ago, this time within the scleroforest. The Casuarinas receded, eucalypts advanced and charcoal saturated the landscape. This theory suggests Casuarina may have been the dominant species within the scleroforest as recently as 7 500 years ago, again severely conflicting with Beck's (1986: 11) theory that their dominance ceased at the start of the last interglacial 130 000 years ago. Fire and drought have dominated evolution of Australian plant species and vegetation types for at least the last 10 million years. Plants have had to contend with extreme heat for short periods during bush fires, hot enough to shatter rocks. They have evolved several methods of surviving these fires which influence not only the appearance of the plants but also the structure of the plant community. Fossil charcoal in Victorian brown coal deposits imply that fires in vegetation have occurred for at least 60 million years (Standing Committee on Forestry 1987, pg. 6). Some accounts extend as far back as 350 million years ago (Oxley 1993, pg. 88). But these early fires could not become a selective force of continental proportions. Lightning fires could - and did. The scleromorphs and grasses

offered abundant fuel suitably dried and cured. A pattern of seasonal aridity and lightning storms stirred the right mixture of fuel and water. Too much rain dampened the fuel, and too few storms reduced the probability of ignition, but against the odds fire spread across the continent (Smith, 1995).

It has also been suggested that fire pushed the biota towards sclerophyll as quickly as the genetic reserves could tolerate. Equally fire released precious nutrients otherwise stockpiled in dead wood or cached in inaccessible forms. While the overall nutrient level of the soil might be degraded, fire kept the existing stock in active circulation. Fire favoured those species already disposed to survive as scleromorphs and it burned maladapted competitors into oblivion, or herded them into fire-safe enclaves (Pyne 1991, pg. 9, as cited in (Smith, 1995 URL: http://online.anu.edu.au/Forestry/fire/ecol/as12.htm).

[3] One of the archaeological sites at the Ngarradj Warde Djobkeng Sites Complex (interim listed 19 December 1978) is the Malakunanja II site, one of the most important within this group, preserving a deep, well-stratified archaeological sequence. Within its deposits are found some of the oldest dated grindstones in Australia. Its lowest occupation deposits, which have been dated using thermoluminescence techniques, could be some of the oldest in Australia, and may be as old as 50- 60000 years before present (See Roberts, Jones, Smith, MA,1990a, 1990b; Robert, Jones, 1994).

The idea that Aboriginal societies evolved a dynamic relationship with their environments, and not simply one in which they were merely dependent on the environment, was slow to emerge in the Australian academy.[3] When the remains of a gracile female unearthed at Lake Mungo in far Western New South Wales was radio-carbon dated at 35,000 (1 500 years BP[3]) a whole paradigm of theories about Aborigines, their origins and society, became obsolete. This date implied a far earlier colonisation of Australia by Aboriginal people than had ever been imagined. Prior to this discovery, the most adventurous estimates were 10,000 years. The clear implication is that Aboriginal people were the first open sea mariners, migrating in many voyages, across the Sunda Sahul Strait.

The earliest date for Aboriginal occupation of the continent so far established is 60,000 years BP. These unimaginable time spans traversed thousands of generations; the rising and falling of ocean levels with the ebb and flow of the ice age, and dramatic changes wrought on climate, and fauna and flora by the gradual drying of the continent.

The preponderance of early and influential European perceptions of Aborigines were of a culture not only frozen in time, but also exhibiting great uniformity throughout the continent. These perceptions were coloured not only by the fact that Aboriginal society was being viewed at a time when it was under great stress during the frontier period, but also by the selectivity of European observations. Some explorers' journals paint a picture of complexity not well understood by their contemporary audiences.

As the cultural relativist paradigm began to replace that of evolutionism in the early Twentieth Century, social anthropologists began to appreciate not only the great richness of Aboriginal social institutions and symbolic life but also the range and diversity of social and religious forms throughout the continent.

It remained for archaeologists much later (in the 1970s and 1980s) to reveal evidence of substantial changes through time, in material culture and economy, which have suggested to many the presence of underlying changes in social organisation and ecology as well. Furthermore as botanists, zoologists, anthropologists and geologists continue to investigate the complex relationships between Aboriginal culture, the plant communities, animal species and the physical environment in general, it emerges that complete dependence on natural bounty is a poor characterisation of the Aboriginal economy. It now appears that this economy has had a substantial impact on the environment, which we recognise today as characteristically Australian. Moreover, the minimalist assumptions of human life during the Pleistocene have been debunked by Allen (1993: 139)

A coherent picture of life during the Pleistocene remains elusive despite the explosion of knowledge in Australian prehistory. The Pleistocene record of Greater Australia has been largely reflected in sites separated from each other by geographical and temporal distances too great to postulate direct historical connections. Secondly, models developed for the Pleistocene have been minimalist. They are dominated by the shortest sea routes, the lowest sea levels and unenterprising technology. Current investigations are reviewing and revising these interpretations. Concerted study of the Greater Australian Pleistocene can already demonstrate variations between regions and hint at least at equally significant changes within regions over time. This paper suggests notions of an unchanging history for Pleistocene humans contained within the minimalist models be discarded.[3]

The ancient Greeks thought this island must exist, and mapped it as a theoretical hypothesis. Spanish, Portuguese and Dutch sailors from the imperial centres of Europe searched for the island until Captain James Cook claimed the eastern half of the continent on the basis of 'first discovery and possession', by such symbolic acts as hoisting a flag in several places along the east coast and finally at the place he called Possession Island in the Torres Strait3, off the north eastern coast.

[4] But are these presumptions of the existence of 'human knowledge' any different from that proposed by Rousseau? In A Discourse on the Origin of Inequality he argued:

> Let us conclude then that man in a state of nature, wandering up and down the forests, without industry, without speech, and without home, an equal stranger to war and to all ties, neither standing in need of his fellow-creatures nor having any desire to hurt them, and perhaps even not distinguishing them one from another; let us conclude that, being self-sufficient and subject to so few passions, he could have no feelings or knowledge but such as befitted his situation; that he felt only his actual necessities, and disregarded everything he did not think himself immediately concerned to notice, and that his understanding made no greater progress than his vanity. If by accident he made any discovery, he was the less able to communicate it to others, as he did not know even his own children. Every art would necessarily perish

with its inventor, where there was no kind of education among men, and generations succeeded generations without the least advance; when, all setting out from the same point, centuries must have elapsed in the barbarism of the first ages; when the race was already old, and man remained a child (Rousseau, 1973).

Rousseau's words echo in the social Darwinist idea of human evolution which posits Europeans as the pinnacle of human evolution and Aborigines and Tierra del Fuegans at the base. This theory is remarkably persistent in late twentieth century Australian polity, science and the humanities. Even though I acknowledge that scholars have legitimate inquiries to make and that their contributions to human knowledge, in many instances, enrich human life, I do not accept these general propositions of the academy as universal and axiomatic. Some claims are embedded in an essentialism which posits Western science as 'human knowledge' and necessarily beneficial, while Aboriginal knowledge, according to this essentialist drama, is not part of the grand tradition of 'human knowledge' because it lies outside the Western traditions of description, classification, verifiability and other precepts of 'science', much in the way that Rousseau concluded.

[5] Langton M, 1993. The Case Study of Jardiwarnpa, in Langton, M., Well I saw it on the radio and I heard it on the television...: an essay for the Australian Film Commission on the politics of filmmaking by and about Aboriginal people and things, Australian Fim Commission, Sydney, 75-80. Peterson N, 1970. Buluwandi: A Central Australian Ceremony for the Resolution of Conflict, in Berndt R.M. (ed), Australian Aboriginal Anthroplogy, University of Western Australia Press for the Australian Institute of Aboriginal Studies, 222-225.

[6] Bright A, 1995. Burn Grass, in Rose DB(ed), Country in Flames; Proceedings of the 1994 symposium on Bio-diversity and Fire in North Australia , Biodiversity Series, Paper No. 3, Biodiversity Unit, Department of Environment, Sport and Territories, Canberra, 59-62.

[7] Maddock K, 1970. Myths of the Acquistion of Fire in Northern and Eastern Australia, in Berndt R.M. (ed), Australian Aboriginal Anthroplogy, University of Western Australia Press for the Australian Institute of Aboriginal Studies, 174-199.

[8] Bradley J, 1995. Fire: emotion and politics: a Yanyuwa case study, in Rose DB (ed), Country in Flames; Proceedings of the 1994 symposium on Bio-diversity and Fire in North Australia, Biodiversity Series, Paper No. 3, Biodiversity Unit, Department of Environment, Sport and Territories, Canberra, 25-32.

[9] The research by Andersen and McKaige[9] and others, has confirmed that tourist responses to northern savanna fires are a powerful reason for the marginalisation of Aboriginal practices in Kakadu.

[10] Bright A, 1995. Burn Grass, in Rose DB(ed), Country in Flames; Proceedings of the 1994 symposium on Bio-diversity and Fire in North Australia, Biodiversity Series, Paper No. 3, Biodiversity Unit, Department of Environment, Sport and Territories, Canberra, 59-62.

[11] See Williams N (1986).

[12] See, in particular, D Thomson (1949)also I. Keen (1989), F Myers, (1982,1986), DB Rose (1988, 1992, 1996).

[13] Jones R, 1969. Firestick Farming, Australian Natural History, September. Also see Jones R, 1995. Mindjongork: legacy of the firestick, in Rose, D. B. (ed.), Country in Flames; Proceedings of the 1994 Symposium on Bio-diversity and Fire in North Australia , Biodiversity Series, Paper No. 3, Biodiversity Unit, Department of Environment, Sport and Territories, Canberra.

[14] Gould R, 1969. Yiwara: foragers of the Australian desert, Scribner, New York.

[15] Hallam S, 1975. Fire and Hearth: a study of Aboriginal useage and European usurpation in south-Western Australia, AIAS, Canberra.

[16] Haynes CD, 1985. The Pattern and ecology of munwag: traditional Aboriginal fire regimes in north central Arnhemland, in MG Ridpath and LK Corbett (eds), Ecology of the Wet-Dry Tropics, Proceedings of the Ecological Society of Australia, Vol 13, Ecological Society of Australia, Canberra, 203-214.

[17] Russell-Smith, J, et al, 1996. Aboriginal Resource Utilisation and Fire Management Practice in Western Arnhem Land, Monsoonal Northern Australia: Notes for Prehistory, Lessons for the Future, Human Ecology, May.

[18] Latz PK, 1995. Bushfires and Bushtucker: Aboriginal Plant use in Central Australia, IAD Press, Alice Springs.

[19] Bowman DM, (forthcoming). 86th Tansley Review. The impact of Aboriginal landscape burning on the Australian biota, in New Phytologist.

[20] Head L. & Hughes C., 1996. One land, which law? Fire in the Northern Territory, in Howitt R, et al (eds), Resources, Nations and Indigenous Peoples. Case Studies from Australasia, Melanesia and Southeast Asia, Oxford University Press, Melbourne.

[21] The preponderance of early and influential European perceptions of Aborigines were of a culture not only frozen in time, but also exhibiting great uniformity throughout the continent. These perceptions were coloured not only by the fact that Aboriginal society was being viewed at a time when it was under great stress during the frontier period, but also by the selectivity of European observations. Some explorers' journals paint a picture of complexity not well understood by their contemporary audiences.

As the cultural relativist paradigm began to replace that of evolutionism in the early Twentieth Century, social anthropologists began to appreciate not only the great richness of Aboriginal social institutions and symbolic life but also the range and diversity of social and religious forms throughout the continent.

[22] pp4-7, (Section 13, Background: Caring for Country, Managing the Natural Heritage of the Park) A Plan of Management in Respect of Kakadu National Park, Kakadu National Park Plan of Management 1997, Commonwealth of Australia, 1997.

[23] pp4-7, (Section 13, Background: Caring for Country, Managing the Natural Heritage of the Park) A Plan of Management in Respect of Kakadu National Park, Kakadu National Park Plan of Management 1997, Commonwealth of Australia, 1997.

[24] pp4-7, (Section 13, Background: Caring for Country, Managing the Natural Heritage of the Park) A Plan of Management in Respect of Kakadu National Park, Kakadu National Park Plan of Management 1997, Commonwealth of Australia, 1997.

How Fire Shaped A Continent: Australian Experiences of Fire Since 1788

Professor Geoffrey Blainey[1]

For most of the last 200 years, fire cooked the meals eaten in Australia. Fire cleared a vast extent of ground for farming, grazing and prospecting, though usually it was not used with the knowledge and skill of Aborigines. Fire was central to the age of steam which began humbly with steamboats in the 1830s and perhaps reached its dominance in land and sea transport the 1920s, by which time the internal combustion engine was soaring in influence. Fire was a crucial agent in the mining and smelting industries, and such towns as Newcastle, Port Kembla, Mt Lyell, Cobar, Whyalla, Port Pirie and Mt Isa relied heavily on fire processes. In daily life, fire provided one of the high hazards and also an occasion for bravery. Fire also provided symbolism to Australian artists though, as Professor Marcia Langton made clear in her challenging address, it was not as important to them, culturally, as it was to the Aborigines.

In addition some of the influential and symbolic events in Australian history were shaped or initiated by fires. In the outbreak of the rebellion at Ballarat in 1854, the burning of Bentley's Hotel was a climactic event which escalated the confrontation between the gold miners and those governing them. In the career of the bushranger Ned Kelly, fire was crucial in the last stages. At a small-town blacksmith's forge, using fire, Kelly turned pieces of ploughs into a cumbersome suit of armour, which he donned for his last fight at the Glenrowan Hotel in 1880. The police set fire to the hotel and later the charred bodies of three bushrangers were found inside.

In the celebrated shearers' dispute of 1894 the paddle steamer Rodney carried free labour or scab labour - depending on your point of view – up the Darling River towards outback stations where the shearers were on strike. One night, trade unionists boarded the ship, captured it, and set it alight.

Fire was often employed as a weapon in times of high excitement and anger. Thus the disastrous fire at the North Lyell mine in Tasmania in 1912 was probably lit deliberately by a militant at a time of tension, though there was no intention of causing the loss of life that ensued. In the fire, 42 men died: the worst disaster in a metalliferous mine in Australia's history. The burning of opponents' flags in today's street processions is part of this tradition. Whether the burning of schools, a practice so frequent today, belongs to this tradition, I do not know.

1 FIRE AND ARTISTS

In the nineteenth century, Australian painters saw the drama of the bushfires and set out to paint them. Strutt, von Guerard and Longstaff all painted big bushfires. John Longstaff's painting of the Gippsland fires of 1898, I think, is the best known. Incidentally all were Victorians, but then Victoria at that time possessed the most painters and probably experienced the most severe bushfires, many of which raged within easy travelling distance of Melbourne.

While a large fire, or evidence of the fire, is rarely to be seen in representational paintings by celebrated modern artists, it is more frequent than I realised when I set out to write this address. Thus Sidney Nolan painted his personal vision of the burning of big Palais de Danse at St Kilda in 1945. Later in his Ned Kelly series, he painted the burned -out hotel at Glenrowan. Arthur Boyd, glimpsing the wheat paddocks in the Victorian Wimmera in 1949-50, painted burned stubble - not burning stubble. The burning of the stubble was an age-old practice and much more frequent in Australia than in Europe. The only fire-centred painting I can recall from the 1990s is by the fine Victorian painter John Howley. He might not agree, but to my eyes and my imagination his painting depicts a ship burning at sea, and breath-taking it is.

Many nineteenth-century artists of ability were fascinated by the Aboriginal fire-lit corroboree, and in mid century they often depicted it or their version of it. In every such painting I have seen, a large

[1] PO Box 257, East Melbourne Vic 3002.

central fire was burning. Whether they were genuine corroborees, or partly arranged for the benefit of the painter and a few friends, I am not able to tell.

John Skipper painted a corroboree in South Australia in 1840, and this oil painting is in the SA Museum. John Glover painted at least three different corroborees in Tasmania in the 1840s, and one can be seen in the art gallery just a few steps from this hall. WFE Liardet painted a corroborees at Emerald Hill, now called South Melbourne, in 1840. Most of these paintings shows a fire burning in the foreground and a full moon in the sky. or at least the visible light of a full moon. One of Glover's paintings shows only a one-third moon. Until I observed these paintings I had not realised that, at least in south east Australia, a corroboree was most likely to be organised for the full moon, but that choice of time makes sense. You can see a variety of corroboree paintings in Geoffrey Dutton's art history called Black and White and published by Macmillan in 1974.

In the days when living poets enjoyed a wide public following, did they describe bushfires? The popular New South Wales poet, Henry Kendall, in "A Death in the Bush", wrote of the 'flying forest-fires'. I can think of only one mention of bushfires in a popular poem - "A Dedication" by Adam Lindsay Gordon who was a friend and drinking mate of Kendall. One of the five best known of his poems, known at one time to maybe several hundred thousands of Australians, it was written in the 1860s:

> They are rhymes rudely strung with intent less
> Of sound than of words,
> In lands where bright blossoms are scentless,
> And songless bright birds
> Where, with fire and fierce drought in her tresses
> Insatiable Summer oppresses
> Sere woodlands and sad wildernesses,
> And faint flocks and herds.

Gordon is now read rarely. Even Henry Lawson's masterly short stories about bushfires, published in 1902 in his volume called The Romance of the Swag, have fallen from favour.

2 TOWN AND RURAL FIRES

I feel pretty sure that fires in towns were more damaging in the19th century than in the late 20th century. For a long period the water supply in towns was inadequate and fire brigades were not co-ordinated. Moreover the news of a fire was slow to reach the brigades and their horse-drawn fire-engines were often slow to teach a fire. Wooden buildings, more common then, were a special danger: so too were live theatres, perhaps because they were vividly lit by gas and perhaps because people smoked pipes inside them. In 1871 and 1872 Melbourne lost two theatres by fire, and Sydney lost its Prince of Wales opera house.

At Sydney in one small period from 1857 to 1862, various ships caught fire. In 1857 the brig Mary Grant caught fire in Darling Harbour. In 1860 the ship Catteau Wattle was burned at Milson's Point and her cargo was destroyed and in the end she was scuttled. In the same year the ship British Merchant caught fire at Smith's Wharf and was scuttled. The famous wooden clipper Sovereign of the Seas caught fire at Circular Quay on 10 September 1861, and 1600 tons of cargo was said to be burned. (Incidentally eight years later at Geelong the fast clipper Lightning - one of the most famous sailing ships in the history of the world - was burned so extensively that she did not sail again). In 1861 the ship Competitor caught fire off Farm Cove and was lucky to escape, and a year later in Mort's Dock the steamer Claud Hamilton caught fire. If a ship in the water can catch fire, so too can an ice house. In Sydney in May 1862 the ice house or ice store owned by Buchanan and Skinner was totally destroyed.

In country towns, where most houses were weatherboard and firewood was the main fuel and candle or kerosene was the main lighting, house fires were frequent. Leongatha, a wooden town in south Gippsland, typified the risk. Its main streets first received pipes of water in 1906 and the town formed an amateur fire brigade in 1907. At the first house-fire to which the new brigade was summoned, the few members who attended realised suddenly why many of their colleagues were absent. It was impossible to assemble the local firemen quickly because there was no phone and no fire bell. In the following year four shops were destroyed in a fire – more would have been destroyed but for the new fire bell that summoned the firemen.

It is likely that most of the Australian towns which suffered a relatively heavy loss of property in a single fire were not the victims of a street fire but a bushfire. A considerable number of Australian towns, standing in the path of a bushfire, have each lost at least 50 shops and houses.

3 MAJOR BUSHFIRES

After the sheep moved onto the inland plains, the danger of grass fires or bush fires was soon apparent to the inexperienced shepherds. The dry climate and low humidity in summer, the strong blast-furnace winds, and the presence of the inflammable eucalypt were together an acute problem.

It is not known when the first shepherd lost his life through fire but it was a portentous event. It is not known when the first flock of sheep suffered from fire, but sheep owners were soon be alert to the fact that they could face insolvency if a serious grass fire swept through the pastures. The small bush towns began to realise that even they were vulnerable.

Fire was so widely and indiscriminately used that the danger of a fire burning out of hand was high. Fire was employed to clear land by graziers and farmers. It was employed by prospectors to clear grass and shrub and enable them to look for outcrops of minerals. It was used by swagmen to punish squatters who did not give them a job. Likewise, the billy had to be boiled, and tens of millions of fires were lit each year - even in say the 1850s -simply to heat the water in the billy. Australia was the great tea drinker of the world, in proportion to population, and much of the tea was drunk after the not-too-clear water had been boiled in a makeshift fireplace, or in none. Firewood was so plentiful that boiling the billy was as common in Australia as it was uncommon in Europe. And here and there and everywhere was practised the busy Australian pastime called ‘burning off’.

A warning system announcing a day of high fire-danger was utterly impractical. There were no weather forecasts, and no way of spreading them even if they existed. The daily newspaper - and even in 1860 the volume of its circulation was small - did not reach remote parts of the bush until days had passed. And how could the authorities think of banning the lighting of an open fire on certain days when a high proportion of the population used an open or half-open fire for cooking and for washing clothes and boiling the billy? Care in lighting an outside fire on a hot, windy, hazardous required common sense and experience, which were still in short supply.

The sheer speed and deadliness of raging fires in the bush took immigrant Australians by surprise. There was nothing like in in the land from which they had come. Floods they knew, droughts on a mild scale they knew, but the wind-driven bushfire was a new experience.

The most astonishing account I have read of a major bushfire emerged from Black Thursday - 6 February 185l. It was almost certainly the worst bushfire experienced in Australia since the arrival of the British. One witness believed it covered an area of Victoria embracing 300 miles in one direction and 150 in another. Most of the dry grassland was alight, a fierce northerly was blowing, and a long funnel of black smoke and debris was swept across Bass Strait. That afternoon, on the north west coast of Tasmania, the smoke coming from Victoria turned a summer day into such darkness that many devout people living not far from Devonport thought that it was the Second Coming. A wonderful description is in the book, Bush Life in Tasmania, written by a Tasmanian settler, James Fenton, and printed in 1891.

In the half century after the Black Thursday of 1850, bushfires were frequent; towns were half-destroyed, and farms and pastoral properties burned; but relatively few lives were lost in any major fire, so far as I can discover Curiously in Victoria, the state most vulnerable to deadly fires, the period 1900 to 1950 proved more disastrous than the preceding 50 years. I say that with some confidence but not complete confidence, because long-run statistics covering deaths through bushfires have yet to be compiled.

Victoria, in the quarter century after the First World War, experienced a phase of intense bushfires in every fifth, sixth or seventh year. Major bushfires occurred in 1919, 1926, 1932 and 1939. Loss of life was sometimes heavy. About fifty people died in the fires of February 1926; and twelve of those lives were lost in a saw milling village called Gilderoy near Warburton. Early in 1932 another 28 people lost their lives in bushfires. In 1939, on the terrible day remembered as Black Friday, 71 Victorians died. It was on

Black Friday that Mrs Gladys Sanderson, the acting post mistress at the little sawmilling town of Noojee stayed by her telephone switchboard, relaying information until the flames reached the post office itself.

In the summer of 1943-44, but especially during the traditional danger months of January and February, another fifty one Victorians died in bushfires. In that summer the grass fires more than the forest fires were the killers. The main sufferer was Derrinallum, a small pastoral town on the grassy plains of Western Victoria.

No other state had casualties to match Victoria's, even on one occasion in the first half of this century. In the second half of this century Tasmania experienced the only bushfire which, in its deadliness, was comparable to those of Victoria. On 7 February 1967, thereafter known as Black Tuesday, 62 Tasmanians were killed by bushfires. The fires of Ash Wednesday in 1983 killed 71 people but the deaths were spread over two states, Victoria and South Australia.

Why were fires so destructive of human life in Victoria during the 50 years after 1900 compared to the 50 years before 1900? The causal factors presumably are various but one or two factors might well be crucial. Obviously more people were living in Victoria in the period 1900-50 and so the number of bushfire deaths might be expected to increase. On the other hand, most of the increase of population in the second period lived not in the country but in the cities where the impact of bushfires was smaller. Then again, one might expect the pre-1900 period to be more hazardous because the clearing of the bush was proceeding on a vigorous scale and fire was a constant weapon in the process of clearing. Likewise rural inhabitants in the first period were less experienced and so they had an inadequate knowledge of the climate, the vegetation, and the dangers of fires suddenly rushing out of control. When you consider all these factors it is not clear that more deaths should have been expected in Victoria in the period 1900-50.

I am merely thinking aloud when I offer two new reasons for the increasing loss of life through bushfires in the years 1900-50. My first reason is that the climate in the south-east of Australia was less favourable to bushfires from the 1850s to the 1880s and more favourable to bushfires in the period from the 1890s to the mid l940s. In the south east quarter of the continent the first period was moister and experienced fewer droughts, whereas the second period was dry and experienced a series of droughts. My summary of climate I take from the report produced in 1976 by CHB Priestley and a small team from the Australian Academy of Science. Entitled a Report of a Committee on Climatic Change, it was actually spurred by the fear at that time that Australia might suffer from the period of global cooling which was widely anticipated.

I am not suggesting that climate is all-important but obviously it is very influential. The fires of Ash Wednesday in February 1983 , incidentally, came at the end of another unusually dry period in south-eastern Australia. That February was the second driest on record in Victoria, and the Victorian wheat harvest of that summer was the lowest in tonnage since the Second World War. I have not checked on the climate in SA at that time but I assume it was dry like Victoria's.

To climate I add a second hypothesis: the relative roles of mining and saw-milling in the vulnerable districts. It is possible that those who lived in or near the thick fast-growth forest in the first period were mostly gold miners. The mines were heavy users of wood for their steam boilers and also for the underground timbering and tended to cut a bare perimeter around the town. Moreover the miners themselves fossicked for firewood and kindling. In short a mining town quickly was surrounded by a rather ugly patch of clearing, of its own making. Moreover, in the face of an approaching bushfire, mines in the bush often had a means of shelter: the shaft. In contrast the saw milling towns were very vulnerable. They had a small population and no large clearing around them. My impression - I have no exact statistics - is that the number of saw mills increased and the number of gold mines decreased in the most dangerous of the Victorian bushfire areas - the mountains and dense forests to the east and north east of Melbourne. Moreover the sawmills pushed deeper into the forests with the aid, after about 1915, of the new motor lorry which replaced the narrow-gauge sawmill train. So the mills penetrated deeper into the tall forests where the bushfires between 1918 and 1939 snuffed the most lives.

The great fires of January 1939, the worst up to that time, were most deadly in the saw milling districts. As the royal commissioner noted of those fires, in consecutive sentences: 'Seventy-one lives were lost. Sixty-nine mills were burned.'

This terrible burst of bushfires in Victoria had led to a search for remedies. In 1939 the Victorian government set up a royal commission presided over by Judge Stretton. His report, a jewel of tight prose, was also observant, it demolished folklore and myths, it exposed poor but accepted practices in professional forestry, and it led to reform. One of the first reforms was the setting up of the Country Fire Authority in Victoria.

Many of you have read the fascinating book by Professor Stephen J. Pyne, a professor at Arizona State University who studied attitudes to bushfires in Australia and completed in 1991 his work, Burning Bush: A Fire History of Australia. He gave high praise to Stretton and his stature and influence, not least his influence on the practice of controlled burning: 'He sought a new codification of fire practices, not their abolition'. Stretton's recommendations were taken up in 1947 by two more of Pyne's heroes:JC Foley, a meteorologist, and RH Luke, a young forester trained at the Creswick forestry school. A wave of new ideas in the prevention and control of bushfires - based on controlled and programmed burning – spread around Australia though they did not apparently reach Tasmania in time to help cope with the 1967 fires around Hobart.

Pyne's book concluded with a simple message. Bushfires would always break out in Australia, and in some regions more than others. They could never be entirely prevented, and some would be extinguished only after a titanic struggle. They could only be minimised and confronted in the most sensible and practical way, so that the losses were as low as possible. The sensible methods would always be based on a digesting of the continent's unique risk and its long experience of fire. Though it was not fully realised at the time, the new approach was really a return to ancient Aboriginal practices.

4 BRAVERY

The two most deadly bushfires in Australia since 1950 occurred in 1967 and 1983. They exposed a new pattern which the NSW bushfires of the l990s tended to confirm. The leafy outer-suburbs with their mass of native trees, or the commuter houses set in forest not far from a capital city, or the beach or holiday houses set in the bush, had together replaced the sawmilling camp as the places most vulnerable to fatal bushfires. The commuter districts, and the new respect for native vegetation, were creating a new danger zone.

While the danger zone may be changing, the calls on bravery have not changed. The fighting of bushfires is part of a long national tradition of civic bravery . I am not sure, however, whether those acts of bravery committed during bushfires have always received adequate public recognition. Undoubtedly the smoke often made them invisible, and sometimes all witnesses to the bravery were killed. Moreover, for a long period, the neighbourhood rural groups which fought bushfires were unorganised in a state or national way and presumably did not know the procedures for gaining access to the national bravery awards. Inspecting the records of the Royal Humane Society of Australasia, which for long was the only national body to make bravery awards, I find that between 1880 and 1920 not one of their top awards commemorated bravery in a bushfire, though bravery in city fires and railway fires was very occasionally honoured, and bravery at sea and in floods and in mining accidents was often honoured. The risk in fighting bushfires fires is high even in this mechanised age, and in the 1983 bushfires, thirteen fire-fighters lost their lives.

Like many topics in Australian history, fire and even bushfire are still wide open for research. Often, in preparing this paper, I asked myself questions but could not find an answer.

5 ADDITIONAL SOURCES

I indicated, while reading my paper, the sources most relevant to the arguments I raised. A few additional sources should be mentioned.

- The theatre and ship fires are listed in JH Heaton, Australian Dictionary of Dates and Men of the Time, George Robertson, Sydney, 1879, pp 98-100.
- The origins of the Leongatha fire-brigade are described in John Murphy, No Parallel: the Woorayl shire, 1888-1988 (Hargreen Publishing Co. 1988, esp. 123-4.
- The bravery awards are listed in Colin Bannister, 7000 Brave Australians: a history of the Royal Humane Society of Australasia 1874-1944, self published l996. My thoughts on Victorian bushfires are an extension of arguments raised in my book Our Side of the Country: the story of Victoria (Pan Macmillan, l991) esp. pp. 181-3, 229-30.

Bushfire Causes

Dr Rodney Weber[1]

ABSTRACT

Bushfire incidents in Australia can be caused in many different ways. Of the possible natural ignition sources, lightning is the major cause and can lead to large area fires in remote locations. However, the majority of all fires in Australia are caused by humans, either deliberately or through negligence. All of the significant recent fire events can be attributed to humans inappropriately using machinery, allowing camp fires to escape, being mischievous, etc. This paper will survey a wide range of ignition sources for bushfires, including lightning, spontaneous combustion, underground smoldering of coal seams, as well as the many ways in which people can be responsible. Interestingly, certain popularly held ideas about the causes of bushfires, such as broken glass focussing the suns rays and cigarettes carelessly discarded, can be shown to be extremely unlikely ignition sources and account for (at most) a few percent of all fires.

1 INTRODUCTION

We are all familiar with some significant bushfire events. As well as these occasional conflagrations, each year there are many hundreds of others in each state and territory of Australia and in many countries around the world.

Each fire has a cause. Certainly, many fires in remote areas begin without a human agent and can be rightly considered to be an "Act of God" or a "Natural Disaster". Often the remote location makes suppression considerably more difficult and the fire will eventually consume fuel over a very large area. Incidentally, some of the largest area fires occur in Alaska and Siberia.

A lot of bushfires, particularly those in and near urban areas, involve human agents. This should come as no great surprise, as we are all made well aware of the potential for destruction of ecosystems and structures by accidental or deliberate fires during adverse weather conditions. It needs to be pointed out that ecosystems in Australia and elsewhere in the world have evolved during a variety of fire regimes. A policy of total fire exclusion would therefore have undesirable ecological consequences. The issue in this paper is really addressing what could be described as "the causes of uncontrolled wildland fires".

Several Australian state authorities have developed an "arson package" for the purpose off training fire investigators to be better able to infer the event that initiated a fire. One particularly comprehensive package comes from the NSW Police Service Academy located in Goulburn. Charles Sturt University has incorporated elements of this package into graduate tertiary qualifications and hopes in this way to assist in the process of certification of fire investigators. By following the classification of bushfire causes used in this "arson package", the present paper will survey selected causative agents and use official statistics from state and national authorities to clearly show that most of the serious bushfire incidents are human caused.

2 BUSHFIRE CAUSES

The classification of bushfire causes as set out in the NSW Police Service Arson package begins by dividing all fires into (1) Accidental, or (2) Deliberate, and continues as shown below. As with any classification, there are certain causative agents, e.g. cigarettes, which could be present in more than one category.

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1 Accidental

(a) Natural
- (i) Lightning Strikes
- (ii) Spontaneous Combustion
- (iii) Glass

(b) Negligence
- (i) Vehicles and / or trains
- (ii) Non-stationary engines
- (iii) Stationary engines
- (iv) Welding, grinding, soldering, or gas cutting implements
- (v) Fuel spill fires
- (vi) Powerlines
- (vii) Escape from Campfires
- (viii) Cigarettes

2 Deliberate --- factors to look for include

- Incendiary Devices
- Close proximity to roads, tracks, trails, urban areas
- Numerous fires close together
- Evidence of human activity
- Previous fires in the same location
- Method of ignition cannot be determined and all accidental causes have been eliminated
- Evidence from eyewitnesses
- Apparent motive

3 IGNITION SCIENCE

The classification of bushfire causes, as given in the previous section, clearly indicates that there are a wide range of possible sources of ignition. While it is impossible to fully survey scientific investigations into all of these sources in a brief paper, there are some useful observations to make on the methods of investigation and the ability to predict likely ignitions.

Beginning with lightning, investigations have ranged from very early attempts with kites (do not try this at home!) to laboratory experiments with very high voltages causing arc discharges into small fuel samples. Incidentally, one experimental set-up at the US Forest Service fire laboratory in Missoula Montana, involved upto twenty truck batteries connected in series to provide a large current with a moderate voltage rather than the very high voltage but low currents usually involved in public science dsiplays, such as those in the science centres around the world. Real lightning combines high voltages and large currents. The prediction of thunderstorm activity is reasonably well covered by the meteorologists. This makes the anticipation of lightning caused fire events a routine part of fire agency operations and also timber managers in places such as Gippsland in Eastern Victoria.

Glass fragments and discarded cigarettes can cause fires, but this a very unlikely source of accidental ignition. There have been various ad hoc and more methodical experiments to try to evaluate the real possibility of ignition from these sources (one such series of experiments was conducted by Countryman in the USA but seems never to have been published in any accessible forum). It is also possible to mathematically estimate the concentration of heat and its effect on vegetation; hence showing these to be unlikely ignition sources unless used deliberately.

Spontaneous combustion (see for example Drysdale, 1999) is the self heating of organic matter such as coal, hay, sugar cane residue and apparently even flood debris. There is a well established scientific procedure for determining the conditions and quantities likely to result in spontaneous ignition for any particular substance. The physical chemistry associated with spontaneous ignition was first identified at the turn of the century and written in mathematical form using the principle of conservation of energy. The rate of the exothermic reaction for the decomposition of organic matter can be well described by the Arrhenius equation, which shows a very strong temperature dependence. Laboratory experiments are required to find suitable values for the physical constants appropriate for each type of organic matter. It is then possible to calculate the minimum size which will self ignite and how this size varies with ambient temperature and other conditions (see for example Weber et al, 1998).

Finally, there is a considerable body of literature on the spread of bushfires after the ignition and also on the propensity of firebrands (burning fuel elements of many possible types) to be lofted into the air and to travel short or sometimes even long distances, resulting in very rapid spread. A useful introduction can be found in Luke and McArthur (1978), more upto date information with an ecological focus can be found a the forthcoming book edited by Johnson and Miyanishi (2000) and recent research is regularly reported in the International Journal of Wildland Fire.

4 SELECTED BUSHFIRE STATISTICS

The collection of information on bushfires and particularly their ignition, is a difficult task. Each state and territory of Australia has different reporting formats and categories which have evolved over time. Nevertheless, for some time the Australian Fire Authorities Council and other representative bodies have attempted to facilitate the compilation of national figures; for example the 1992-1993 Australian Fire Incident Statistics published by CSIRO in 1995. From these, one can form a reasonable picture of the ignition causes by events and also by areas burnt. For example, in the Australian Capital Territory, lightning accounts for three to five per cent of fires each year, there is on average one fire per year attributed to spontaneous ignition (either in mulch heaps or occassionally in flood debris) and people are responsible for over 90% of all fires, with a small number of serial arsonists well and truly over represented in the statistics. A spokesman from the ACT Bushfire Council has recently been quoted saying that the number of fires is doubling every decade, but one would hope that this is an overestimate.

In Figure 1, we see the ignition factors for fires in NSW in the 1996/97 fire season.

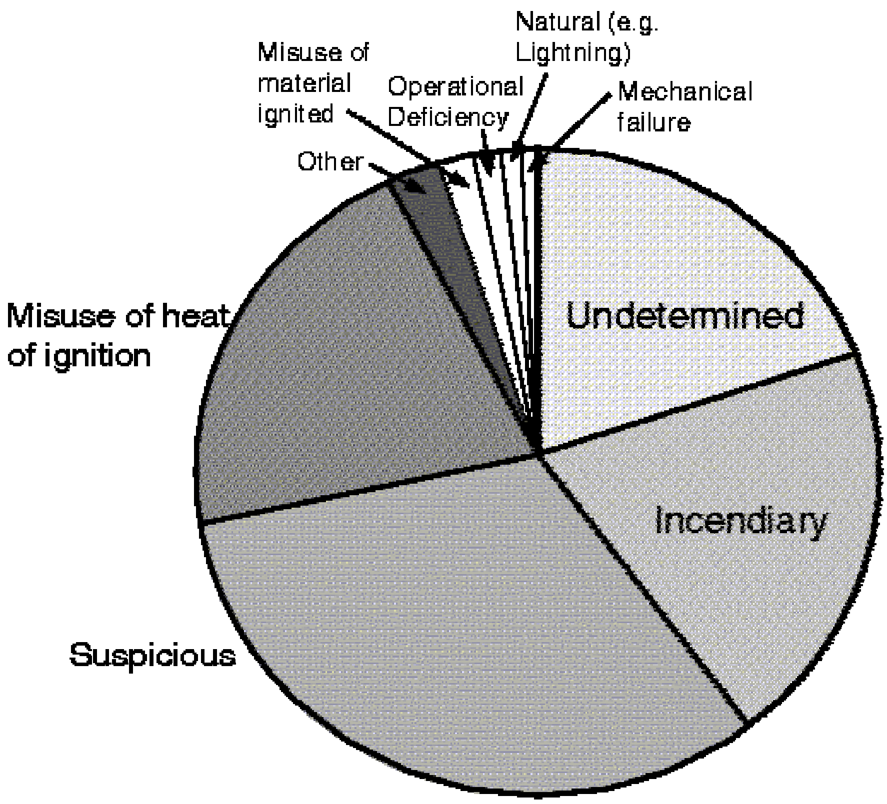

Figure 1 - Fire causes by percentage of total fires for NSW 1996/97

While there is clearly a large proportion of fires for which it was not possible to determine the cause, it is nevertheless obvious that natural factors, such as lightning, play a minor role in the number of fires ignited.

In Figures 2 and 3, we see a summary of twenty years of data collection on fire causes on public land across Victoria.

Looking at the total number of fires in Figure 2, it is clear that approximately one quarter are caused by lightning, one quarter are deliberately lit and the remaining half are due to various human related activities. In Figure 3 we see that although lightning is the cause of only one quarter of the number of all fires on public land in Victoria, lightning fires are responsible for nearly half of the total area burned.

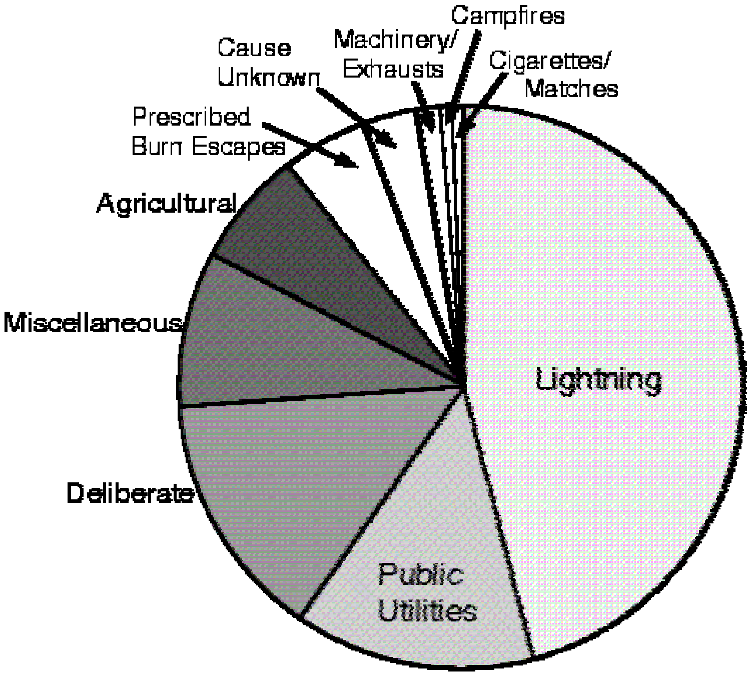

Figure 2 - Fire causes by percentage of total fires for Victoria, 1976-1996

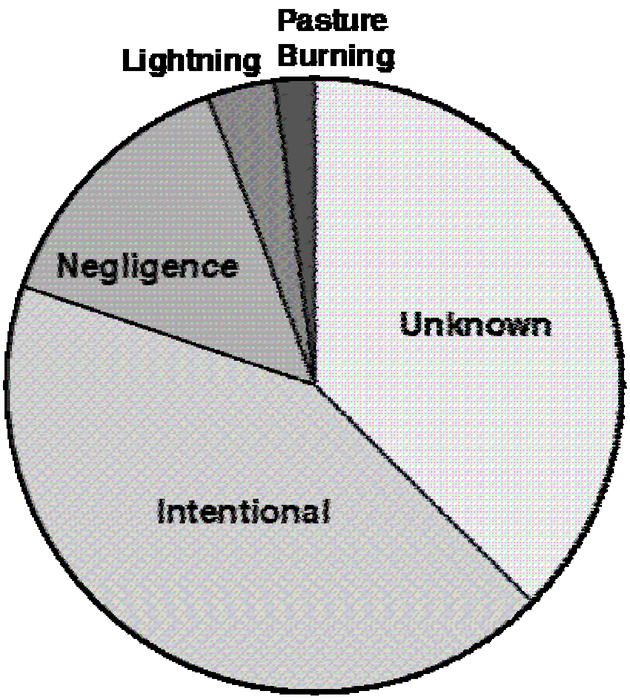

Figure 3 - Fire causes by percentage of area burnt for Victoria, 1976-1996

It would be of great interest to put an economic value on each fire incident and then display the dollar value of fires according to ignition causes. The remote nature of most large lightning fires would most likely mean that the major economic loss in bushfires is due to the deliberate and negligent activities of people. This is not to say that genuine accidents do not occur; rather, it is clear that they are quite rare.

Finally, it is of interest to compare the situation in Australia with other countries. For example, in Spain the fire causes are classified similarly and the experience over twenty years is familiar; as shown in Figures 4 and 5.

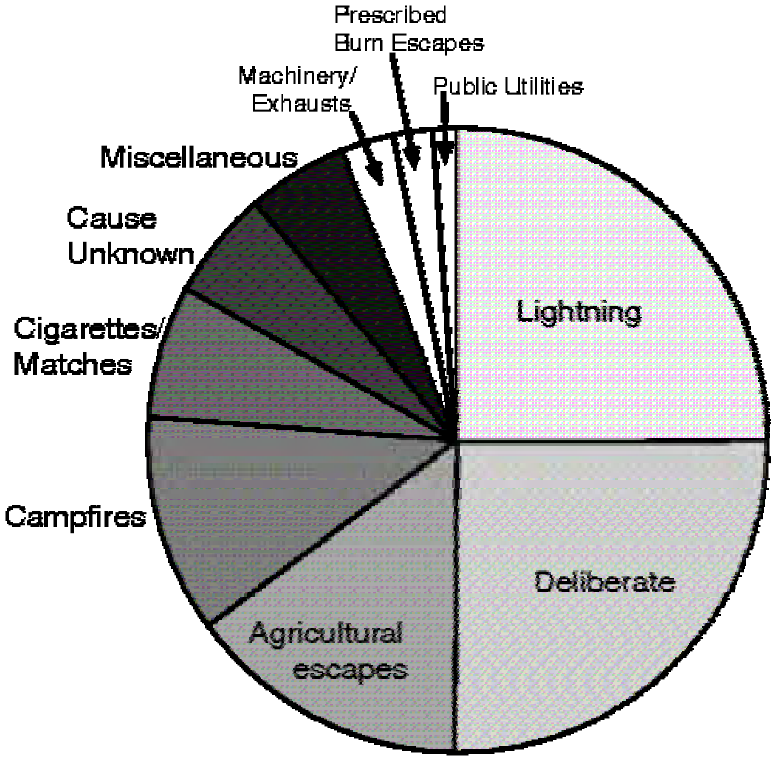

Figure 4 - Fire causes by percentage of total fires for Spain, 1974-94

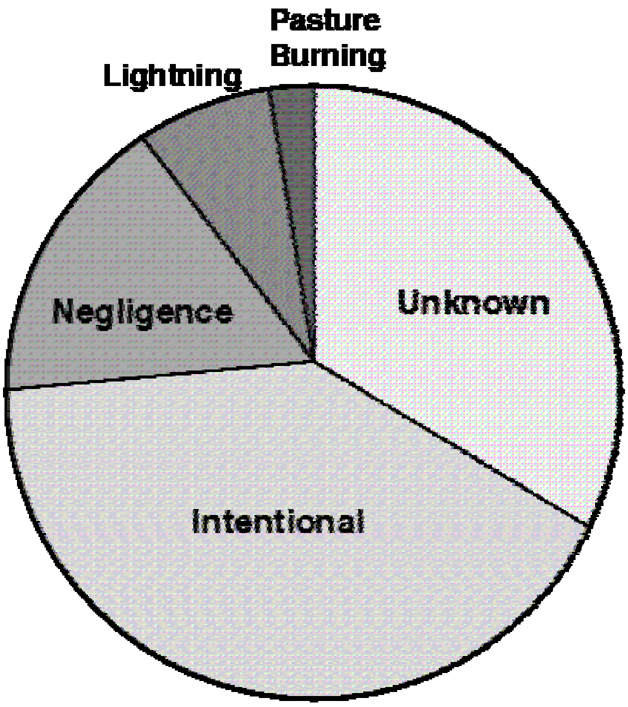

Figure 5 - Fire causes by percentage of area burnt for Spain, 1974-94

Lightning is an important ignition source in selected regions of Russia, Finland, South Africa, Canada and the USA. In particular, in the coniferous forests of British Columbia, Canada and the western USW, up to 60% of all forest fires are caused by lightning. Nowhere is this more pronounced than in the North American boreal forests, where up to 90% of the area burned is due to lightning ignitions. Despite this startling statistic, the major wildland fire concern among the North American community is related to the urban/rural interface and the damage to property from fires, most of which are caused by people.

5 ACKNOWLEDGEMENTS

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The Arsonist's Mind

Mr Fabian Crowe[1]

ABSTRACT

In most statutes, any fire that is lit with the intent to destroy or damage property is regarded as arson. Given this definition, the characteristics and motivation of an arsonist must be violent in nature. In Australia, any person who deliberately lights a fire in rural or forest areas during hot, dry, windy conditions must be considered to have had the intent to cause damage and destruction.

Much of the literature about arson behaviour suggests that the primary motivations for lighting fires are revenge, anger, hostility and the excitement or fascination derived from the fire itself and the response that it generates from the community. People of this disposition exist in most communities. However they don't they do not light fires every day, nor do they light fires on every hot, dry, windy day.

A limited study suggests that, very often, the factors that provide the trigger for people to light fires in the bush during high fire danger conditions appear to be associated with the high profile given to the potential of wildfires when such conditions occur. It is also evident that the profile given to actual wildfire events by the fire agencies and the media can provide the stimuli for more fires to occur.

During other periods of the year, it is evident that many fires recorded as deliberately lit are not adequately investigated to determine who was responsible or to establish the possible motives for such behaviour. It is evident that in most instances, this is due to the fact most of the fires are small and/or pose little immediate threat to the community. It is also attributable to local attitudes where it is perceived that such fires are justifiable or at least do not warrant the cost of a detailed investigation.

1 BACKGROUND

Over the past 5 years in Victoria, between 25 and 35% of all the wildfires which occurred in or immediately adjacent to State forests and National parks were recorded as deliberately lit. In Western Australia, over the same period, the figures are almost identical. However within Victoria, some regions have recorded percentages as high as 60% and others as low as 5%. In the Shire of Shoalhaven on the New South Wales south coast, the percentage of deliberately lit wildfires in one year was recorded as 82%.

Despite these statistics, the number of people responsible for these fires is unknown. The detection rates for arson and other fire related offences are very low. In fact, fire agencies in Australia have just recently developed the processes and techniques for determining the origin and cause of wildfires. We have yet to develop the necessary knowledge and skill to improve the rate of detection. We learn a certain amount each time we identify the persons responsible, but we do not use such opportunities to develop an understanding of their motivation and what triggers them to light up when they do. Literature on the characteristics of serial arsonists does help to a certain extent, but there is a very wide range of circumstances and underlying factors in the rural and forest environment that provide the stimulus for lighting fires.

The history of devastating fire events in Australia, particularly those forest fires that have impinged upon rural and urban environments, has caused the psyche of those who live in such environments to fear fire. The culture of rural volunteer fire brigades evolves from the ever-present threat of wildfires and the need to address the community's fear of wildfire. In addition to these factors, fire is a legitimate tool for land management purposes in both agricultural and forest environments.

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2 FIRES LIT WITH MALICIOUS INTENT

In most statutes, any fire that is lit with the intent to destroy or damage property by fire is regarded as arson. Given this definition, the characteristics and motivation of an arsonist must be violent in nature. In Australia, any person who deliberately lights a fire in vegetation during hot, dry, windy conditions must be considered to have had the intent to cause damage and destruction. Much of the literature about arson behaviour suggests that the primary motivations for lighting fires are revenge, anger, hostility and the excitement or fascination derived from the fire itself and the response that it generates from the community. People of this disposition are out there in most communities. They don't they light fires every day, nor do they light fires on every hot, dry, windy day. However those who are serial arsonists, do tend to light bigger fires over time – inflicting greater damage, or at least posing greater threat.

Clifford L. Karchmer, in his paper - "Preventing Arson Epidemics – The Role of Early Warning Strategies", suggests that underlying the motives of revenge, anger, hostility and excitement was the arsonist's need to feel the sense of power when they lit fires and watched the devastation they wreaked.

Of those who have been apprehended for lighting fires with malicious intent, the range of underlying factors and personal circumstances that apparently caused them to light the fires included one or more of the following:

- deprivation or denial of position or status within their community or organisation;
- domestic conflict and / or lack of recognition of personal position or status;
- dismay and frustration with current land use practices.

However the question still remains - what triggers them to light up when they do?

3 FIRES LIT FOR LAND MANAGEMENT PURPOSES

In a rural context, fire is used to reduce fuel hazards, to stimulate the regeneration of vegetation, and to remove pest plants, fallen timber and post harvest residue. Such fires tend to be lit on the shoulders of the fire season when the target fuels are dry enough to burn, but the conditions are less likely to cause the fire to spread and cause damage. However in some instances, it is evident that the person responsible did not care if their fire escaped – particularly if what was going to burn was – *"…only a bit of bush"*.

Often fire agencies and the Police see these fires as a relatively minor breach of legislation. As a result, if and when they are investigated, they are dealt with in the lower courts. Some are even dealt with by expiation processes. However the motives and underlying reasons why such fires are lit or left to burn are often associated with a resentment towards the Government and perceptions about the threat of fire or the limits imposed on the use of that land.

These motives are not dissimilar to those of an arsonist. The only difference is that the intent does not include causing harm to life or property. To some, Government land does not constitute property and in many instances, there is a perception that any fire which burns forest or scrub is justifiable. This apparent acceptance of such conduct does not discourage the continuation of the practice within the community and as a result those individuals who may have a disposition towards lighting fires may be encouraged by the fact that little attention is given to fires of this nature. As a result, unwanted fires continue and potential arsonists go undetected.

4 FIRES LIT WHERE THE PURPOSE IS UNKNOWN

There are many fires that are deliberately lit in rural and forest areas where the objective or motive for lighting the fire is unclear. As with those fires discussed under the previous heading, too many fires escape the attention of investigators because all that was burnt was - "…a bit of scrub". The culture within rural fire agencies tends to be dismissive of the need to determine the origin and cause of most small wildfires. The attitudes - "… It didn't do any harm" and - "…The bush needed a good burn anyway" are reflected in the conduct of first attending crews, in the recording of fire causes and in the nature of investigations conducted. As a result, the real motivations for these fires go unrecognised, and many of those that are lit by people who have an unhealthy attitude towards fires and the community are not properly examined.

These are the incidents that require the most attention. Potentially they are the 'breeding-grounds' for future arsonists. Without a thorough investigation of these small fires we cannot hope to identify those who have a tendency to light fires nor can we help them overcome such tendencies or prevent them from lighting larger, more serious fires. Every fire that is not investigated is a lost opportunity to develop a better understanding of the psyche of firelighters and the triggers that cause them to light fires.

5 CASE STUDIES

The following case studies are provided as examples to illustrate a range of circumstances under which fires are lit. All show that the literature about the characteristics of an arsonist is correct. However, in each instance there was a trigger – either one generated by the fire services and the media, or an incident at a local level which stimulated them to light that fire.

5.1 New South Wales – 1994

Between December 27, 1993 and January 16, 1994, more than 800 wildfires occurred in New South Wales.

In summary, these events were predicated by unseaonally dry conditions – particularly along the East Coast. In late December there were more than 100 wildfires burning across the State. These included fires in the Great Lakes area, the Hunter region, the Wollongong area, and near Grafton on the north coast. While there is little information available to indicate who started these fires, there is little doubt that the majority were deliberately lit. There is also little doubt that the 600 or more fires that followed in the next 10 to 12 days were also deliberately lit.(5) One has to question whether the role of the media, government and fire agency officials leading up to and during these even ts contributed in any way to these additional fires.

The fires that were burning generated considerable media interest. In the Grafton area, in particular, the fires provided some spectacular television footage. The media coverage was widespread, live and in people's homes 24 hours a day. Some of the fires were "talked-up" as being *"the worst since 1968"*. In interviews, firefighters and people affected by these fires provided emotional and colourful word pictures of rampaging, uncontrollable fire storms and stories of near misses and destruction. When three firefighters died on January 4, senior public figures spoke to the media using phrases such as:

- *"Wonderful… heroic… volunteers who laid their lives on the line to fight the merciless blazes."*
- *"It is evident that many of these fires were deliberately lit."*
- *"Unfortunately it is virtually impossible to detect people who light fires in the bush."*
- *"The last thing we want now is a fire in the Blue Mountains."*

Were these statements, and the associated extensive media coverage about the continuing extreme fire danger, factors that triggered another 600 wildfires that occurred across NSW in the following period? We will never know unless the persons responsible are apprehended.

Some of the possible scenarios/thought processes of the people who caused these fires may have included any one or more of the following:

- *"There is no excitement here in my neighbourhood."* (Flames, confusion, lights and sirens)
- *"Those people over there are getting all the attention."* (Heroes, 15 seconds of fame on TV)
- *"Well if it's virtually impossible to get caught, I might as well take the opportunity to burn that bloody national park."* (It's a hazard the National Parks people won't clear up.)
- *"I could light a better fire than they could."* (Bigger and better)
- *"I'll show them."* (Getting even with neighbours, former employers, government, etc.)
- *"Just to make sure we are going to be put to good use."* (More firefighters are called upon to assist)
- *"More, more, more."* (Firefighters and or individuals who want more excitement)
- *"There is some money in this."* (Paid firefighters, local businesses, contractors, etc)

5.2 Victoria - 1997

On January 20, 1997, several fires occurred on the Mornington Peninsula, south of Melbourne. Once again the images of spectacular flames and smoke columns were shown on television – even during the coverage of the Australian Tennis Open. The front pages of the daily newspapers also depicted photographs of flames, large numbers of firefighters, fire trucks and helicopters. The fire agencies "talked-up" the fact that the forecast for the next day was for "even worse" conditions and a day of Total Fire Ban was declared.

The scenario that followed on 21 January was very similar to that which occurred in NSW. Five fires were lit in the Dandenong Ranges National park, a forest/urban interface zone with a history of infrequent but devastating fires. Over 120 other fires were burning in other parts of the State. Fortunately, Victoria did not experience an extended hot dry spell after January 21. This milder weather prevented the circumstances that which occurred in NSW in 1994.

No person has been charged for any of these events so the motivation or trigger that caused the person responsible to light these fires remains unknown. However, there were several features about the circumstances under which these fires were lit that should convince that the intent was, in fact, to cause destruction:

- All of the fires were lit within the space of 120 minutes.
- All were lit where they were going to spread rapidly up the slope, in heavily forested areas, under the influence of strong winds.
- All were lit in isolated locations, adjacent to little-used tracks.
- All were lit below settlements that were located on the ridges above.
- There is little doubt that the person responsible had knowledge of fire behaviour, of the local area and of the potential impact.

Was one of the triggers for lighting the fires associated with the publicity? Why were the fires lit to cause maximum harm and destruction?

5.3 Victoria – 1992 to 1995

In the 1992/93-fire season, the first of a series of fires occurred in the native forests and pine plantations around Ballarat, a provincial centre west of Melbourne. While this fire was relatively small, lit adjacent to a little-used road, the series of fires that followed during that season and the following season all exhibited a disturbing trend. After the first three fires, the sites and times chosen for setting the subsequent fires were in circumstances where there was potential for large, high intensity fires to develop. The most recent fires caused substantial damage to pine plantations and included fires lit to destroy two houses, several haystacks and a number of vehicles.

The person responsible was apprehended and subsequently convicted for a number of the fires.

During the hearing, a clinical psychologist described the defendant as - *"…a pyromaniac…with an impulse control disorder"* and that he suffered from - *"…an insatiable compulsion to light fires, to view fires and to read about fires"*.

Interviews conducted with the defendant both prior to and since the hearing clearly suggest that he has a disposition towards violence. He was convicted for a series of hedge fires in the Melbourne suburbs during 1988 and 1989 and had other convictions for burglary, assault and theft. He is also fascinated with fire. This interest is stimulated by a combination of the flames, the lights and sirens that are associated with the response, and the subsequent publicity. He has posters and photographs of fire and fire appliances on his bedroom walls. He also has a collection of newspaper clippings of fire events – particularly those for which he was responsible.

5.4 Victoria – Castlemaine - 1990 – 1993

During the fire seasons of 1990/91, 1991/92 and 1992/93 an average of 18 fires were deliberately lit each year in the forest near Castlemaine, north west of Melbourne.

Each of these fires was lit on a day preceding a forecast of high fire danger conditions. Each fire was lit so that it would burn down a slope towards a barrier that would contain its spread. All but one of these fires was readily controlled by the fire agencies at less than 10 hectares.

Clearly the motive did not include the intent to cause extensive damage, but never the less it was apparent that the intent was to cause the fire agencies to respond, ensuring that the fires were controlled prior to the forecast high fire danger conditions. It was also apparent that the person responsible was familiar with fire behaviour and fire weather conditions as well as the local district. Once these patterns and characteristics were identified, the task of identifying the person responsible became easier.

When interviewed in relation to these fire events, one of the first statements he made was *"I didn't light the one on Breakneck Track"*. It would appear that he didn't want to be seen to be responsible for the one fire that burnt more than 50 hectares and presented fire crews with some very real control problems. It became evident during the interview that the motivation for lighting the fires was driven by hurt feelings and a desire to 'get back at' those who voted him out of office when his rural brigade amalgamated with the local town brigade. It was also evident that he believed that his position and prestige within the community had been unfairly diminished.

It is also worth noting that his wife was a person of some status in the community, often mentioned and quoted in the local media for her work with the disadvantaged. His attitude towards his wife's work tended to be disparaging and he exhibited scorn towards her when she appeared at the Police station to support him.

5.5 South Australia 1997

In the1996/97 fire season, four fires occurred within close proximity to a small township in southeastern South Australia.

The first three fires were relatively benign and very little effort was required by the local fire brigade to control them. However the fourth fire occurred on an extreme fire danger day and burned a large area of pine plantation and threatened the township.

No person has been charged for lighting these fires. However, it is very evident from interviews conducted with a number of persons in that community, including the suspect, that the trigger for these events emanated from a discussion between the suspect and a person who was a senior member of the local fire brigade. The discussion included the potential for high fire danger in the forthcoming fire season and how the suspect might help out by joining the local brigade. During the conversation, the brigade member suggested, flippantly, that there needed to be a couple of fires "*…to get everybody on their toes*".

The first fire occurred within 48 hours of that conversation and the suspect attended this and each of the other fires with the said member of the brigade.

While there is insufficient evidence at this stage to initiate proceedings against the suspect in this case, he does fit the profile of an arsonist. He had failed to complete his secondary education, he found it difficult to gain permanent employment, and he was struggling to maintain a relationship with his girlfriend who lived in the local community. During the interview, he admitted that he had a high regard for the brigade member and that he was anxious to please him in any way possible. It was also evident that he had little appreciation of the impact and potential threat of the large fire, however he did admit that he thought the firefight was exciting.

Was the flippant remark about the need for a few fires sufficient to cause a person to light these fires?

6 DISCUSSION

While it is not sound practice to rely solely on profiling in investigative processes, in my experience there are some personality traits or characteristics that are common amongst arsonists that have assisted in determining who was responsible for lighting a fire.

It is probably ambitious to ask people to draw conclusions based on a few select examples. However I believe the examples provided all illustrate that there were events and/or circumstances that provided the trigger for the people concerned to light the fires when they did. Numerous other examples could be provided where an outside influence appears to have provided a trigger.

The literature also suggests that many people who light fires do so to gain attention. Once again this factor seems to be reflected in the examples given and other cases that we have examined. Those who have been apprehended for fire lighting have all exhibited poor social skills and a lack of self-esteem. All were low or under-achievers - both academically and in the work place, and in almost all cases, they appear to have lit fires to convey a response to the events or circumstances around them.

The rate of detection and conviction for deliberately lit fires is very low. However, where the people responsible have been identified, a high proportion are members of a volunteer brigade. While one could expect that many members of a fire brigade would have an interest in fire, the majority do have a healthy respect for it and the community they serve. It is this interest and concern for the community that helps identify those members who have the characteristics of an arsonist, and can assist in determining whether any of those individuals had the opportunity to light the fires in question.

7 SUMMARY

1. The culture within fire services is to "talk up" the high fire danger and the potential for damaging fires.
2. The culture within fire services and the media is to "talk up" a fire event when it happens. Images and stories of spectacular flames, numerous firefighters, fire trucks and aircraft, damage, destruction and trauma, all make "good press".
3. The culture within fire services and the media is to "talk up" the heroic efforts of firefighters, particularly the volunteers.
4. Arsonists do not light fires every day, nor do they light them on every hot, dry, windy day.
   It is evident that the factors mentioned in points 1, 2 and 3 above, provide the trigger for some people who have a disposition towards lighting fires to light them during high fire danger conditions.
5. Fires lit for land management purposes rarely occur during the peak of the fire season. However some escape because little care is taken to prevent it from happening.
   This non-conformist attitude towards the regulation of fire is based on traditional perceptions about fire in the natural environment. In some instances, fires lit or left to burn without controls could be construed to be arson.
6. The detection of people responsible for lighting fires is very low.
7. A common thread in instances of serial ignitions is that fires get bigger.
   One of the factors that contribute to the issues mentioned in points 6 and 7 is the fact that many fire managers fail to recognise the long-term benefits of thoroughly investigating all fires. To do so might the incidence and size of fires and the motives of those responsible might be better understood and addressed.
8. Volunteer firefighters are often unfairly labelled as arsonists.
   Those few volunteers who are identified as firelighters are easier to identify because their colleagues notice their 'unusual' or suspicious behaviour.

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Cycles Of Fire; Cycles Of Life

Dr Malcolm Gill[1]

ABSTRACT

In Australia's fire-prone landscapes, cycles of fire and cycles of life interact such that most plant and animal species persist while some can become locally extinct. How this happens is the topic of this chapter. Cycles of fire may have a typical length but, just like the life cycles of plants and animals, they show considerable variation around the average. Similarly, just as birth of animals – the initiation of the life cycle - takes place, on average, at certain times of year, so to does the start of the fire cycle. While there is a usual season for the beginning of life cycles, and fire cycles, there is variation too. Furthermore, just as the properties of the newly born vary, so too do the properties of fires. The difference between fire cycles and life cycles is that fires punctuate time whereas life cycles encompass it. Both cycles can take hundreds of years in natural systems. Some life cycles, however, may take a day or less while the shortest average fire cycle is considered to a year or so. In the mountain ash forests of Victoria where the Leadbeaters Possum lives in tree hollows, the average fire cycle for tree-killing fires is about 100 years while that for any fire – tree killing or not - is about 50 years; for the possum species to survive under these conditions, the intervals between these fires must be variable. The mountain ash trees depend directly on fires for their existence while the hollows depend on the presence of old trees but can form in the absence of fire. The possums depend on the hollows, and other habitat features related to fires, thus indirectly on the fire cycle. The mountain-ash forest example is the result of extensive observation and measurement by professional scientists and by enthusiastic amateurs. There is a need for competent observers throughout Australia to further our knowledge of the interactions of the life cycles of the biota with those of fires.

1 INTRODUCTION

"*Blown by a wind of great force, they roared as they travelled. Balls of crackling fire sped at a great pace in advance of the fires, consuming with a roaring, explosive noise all they touched*."

(Judge LEB Stretton reporting on the 1939 fires in Victoria.)

When 'bushfire' is mentioned, a common perception is of a frightening wall of leaping flames bearing down on houses and people amid showers of sparks driven by a searing wind. Bushfires can be like this but even parts of such 'drama' fires can be of much lower intensity. People carry the vision of the drama fire into their discussions and arguments about fires in the natural landscape; they seem to equate the effect of the drama fire on houses and people with the effect of fires on vegetation and animals.

'Vegetation' and 'animals' are parts of the spectrum of biodiversity components. 'The variety of life' expresses the idea in a fulsome way but, even so, 'biodiversity' is different things to different people. Plant and animal species constitute the traditional element of biodiversity but 'genes' and 'communities' are more recent inclusions. Here, below, I concentrate on populations of particular species in a particular plant community in a particular ecosystem.

The conservation of biodiversity has become an agreed objective for Australia, through international agreements, and for land management agencies in the States and Territories of Australia, usually by legislation. How does this biodiversity survive given the popular idea of the drama fire and the 'destruction' of the vegetation so often reported by the media? This article

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examines, by case history, how fires in the landscape interact with the variety of organisms to be found there. The case history used is that of the superb Mountain Ash forests of southeastern Australia. This example is chosen because of the principles it illustrates and the amount of information available on fires and their effects in this ecosystem.

2 CYCLES OF LIFE

"*The life cycle … is the unit of evolution, the unit of innovation and elimination, and it is for this reason more than any other that the life cycle has a central position in the structure of biology*."

Professor John Tyler Bonner (1965).

All of us count the day on which we were born as the first significant event in our life cycle, the date from which our age is counted. We are born, mature and eventually die; this is our 'life cycle'. If we have children, our genes are passed on to take part in another life cycle. In these personal human terms we can easily recognize that there is variation in the length of the life cycle as generations pass; we attain different ages. Times of birth vary too even though there may be peaks in seasons of birth, like spring, through generations.

The individual's 'life cycle' is not a 'cycle' in the sense of a perfect circle because each individual does not return to a previous condition. It is called a cycle because it represents the processes of life that enough members of the species experience for the species to persist. There is a continual process of birth, maturity, reproduction, birth, maturity, reproduction etc.

The principle of the life cycle extends to all living organisms. 'Birth' may mean delivery of a baby to humans and have obvious similarities among other vertebrate animals but for organisms like plants ' birth' may be translated into 'germination' for some species, cloning in others. 'Birth', or its equivalents, signifies the event representing the beginning of the life cycle.

Variation is an important theme in this essay. The length of a generation varies from minutes to decades (Bonner 1965) while the life span can extend to over a thousand years for some plants. This is the variation between species. Within a species there is variation too. Again, using people as an analogy, the average life span may be 75 years but there is a great deal of variation between individuals.

3 CYCLES OF FIRE

"*The long-term effect of a particular frequency of burning must be recognized*."

Professor WD Jackson (1968)

The drama fire, like any fire, is a discrete event. Fire engines are despatched, fire fighters spring into action, planes deliver water and chemicals, reporters scramble and the fire spreads. Then the wind drops, rain may fall, the tumult subsides, the fire fighters mop up the aftermath, and the populace breathes a sigh of relief. The event is over.

In any one place in the landscape, the fire event marks the start of a new fire cycle. The 'cycle' in this case is marked by the recurrence of fire. In nature, each fire event is just the latest in a long series of events, a sequence of fire cycles. Each fire triggers changes in the ecosystem which could be seen as the beginnings of ecosystem 'cycles'.

Average fire-cycle lengths vary widely across the country. In the northern savanna, the average interval is probably between one and two years (Walker 1981). In the rainforests of Tasmania, 300 years may be the average (Jackson 1968). While cycles of fire may have a typical length in any one place, they show considerable variation around the average as well. Variation in the length of the cycle may take place as the result of the variation in the chance of an ignition at a point (Johnson and Gutsell 1994, Gill and McCarthy 1998, McCarthy, Gill and Bradstock in press) but include variation added to this as well (Gill, Moore, Bradstock and McCarthy, in prep.). Just how much variation there is, and has been, in the fire cycle is the subject of current research.

Variation extends to the characteristics of fires within and between events. This may be obvious from what has already been said. Low intensity fires have short flames and generate relatively little heat; high intensity fires have long flames and release large quantities of heat in a short time. Using the standard fire intensity measure (kWm^{-1}), fire intensity probably varies over 4 orders of magnitude. This is not to say that at any one point on the landscape this range occurs. In some ecosystems such a range is not possible because of the constraints of fuel and weather. Most points in the natural landscape will experience low intensity fires rather than high intensity ones (see Cary and Banks in press). The maximum fire intensity occurring in Australia is unknown, only predicted (Gill and Moore 1990), and may not be measured because of safety considerations, let alone knowing when and at which site such intensities could occur. When fires burn in peat, smouldering and low spread rates predominate, and major ecological consequences can occur (Gill 1996, Wark 1997).

The initiation of the fire cycle takes place, on average, at certain times of year. While there is a usual season for the beginning of fire cycles, like life cycles, there is variation too. Variation can be natural or induced by deliberate management action, or be the result of arson or accident.

Each fire event has consequences. There can be stem death and resprouting of plants; there can be whole plant death and a flush of germinants; there can be increased predation of animals; and, preferential grazing on a 'green pick'. There will be less fuel, shorter plant heights; fewer vertebrate animals and insects. These consequences may mean that there are depletions in seed stores in the soil or on the plant; there may be greater sensitivity of some species of trees to fire because of bark thinning an short stature; there may be species with no reproductive backup if a cohort is eliminated. Depending on how long such consequences last, the previous fire event establishes the conditions for the next fire event. Fuels accumulate as a consequence of time since the previous fire, plants grow in stature as time since the last fire increases *etc.* Thus the conditions at the time of a fire may depend on the effects of generations of fires.

The generations of fires that cross a point in the landscape, all with different properties, and all within a particular, but varying, seasonal range are summed up in the term 'fire regime' (Gill 1975). Because of the carryover effects of each fire, a principle of ecology is that the long-term effects of fires are a consequence of the fire regime (*e.g.* Gill, Bradstock and Williams in prep.).

4 MOUNTAIN-ASH ECOSYSTEMS

"*The ecology of the wet sclerophyll forests therefore hangs on an extraordinarily fine thread. It seems almost inconceivable that the small capsules of these species ... can protect seed … in the holocaust of raging crown fires.*"

Dr DH Ashton (1981), a 'student' of Mountain Ash forests for 50 years.

4.1 The Ecosystem

In Central Victoria these forests grow in tableland and mountain country where the rainfall is high, often on deep soils. At higher elevations the related alpine ash forest is found while at even higher altitudes, Snow Gum woodlands predominate. On the lower side of the Mountain Ash forests are forests of Messmate (*E. obliqua*) and associated eucalypts (such as *E. radiata* and *E. cypellocarpa*).

'The tallest hardwood forests in the world' are the headline for the mountain ash (*Eucalyptus regnans*) forests of southeastern Australia. Mature forests of this species are tall enough to have an understorey of trees as well as shrubs, herbs, and ferns. Ashton and Martin (1996a) recorded 50 species of vascular plant in their collective $120m^2$ area of quadrats, coincidentally the same number of species of mosses and lichens found in the forest but over a broader area (Ashton 1986). Fifty species is but a sample of a vascular flora, however, as Ashton (1981) in a review noted 101 species, 63% of which were herbaceous (64 species herbaceous, 37 woody). Lichens and mosses may proliferate on the bases of the trees, on rocks and on fallen logs (Ashton 1986). Tree ferns are a feature in places.

Of the variety of wildlife found in mountain ash forests, the Lyrebird (*Menura novaehollandiae*) is a popular species but only one of the 65 species of regular avian inhabitants recorded in managed forests by Lloyn (1985). Brown and Nelson (1993) found six species of reptiles in their survey of mountain ash sites. There are six species of bats and the same number of small mammals (MacFarlane 1988). Among the eight species of arboreal animals the Mountain Possum, *Trichosurus caninus* and Leadbeaters Possum, *Gymnobelideus leadbeateri* (MacFarlane 1988, Lindenmayer 1996) are notable. Wallabies (*Wallabia bicolor*) and wombats (*Vombatus urcinus*) are a feature of the ground stratum (see MacFarlane 1988).

4.2 Fire Regimes

Although the climate is wet, droughts occur and predispose the forests to fire. Fuel loads can be substantial, slopes can be steep and, as a result, fire intensities can be very high. Because the droughts are uncommon, the intervals between fires are relatively rare. Using a number of sources of evidence, McCarthy, Gill and Lindenmayer (in press) considered that the most likely interval between tree-killing fires was about 100 years while the interval between fires that burnt the understorey without necessarily killing the trees was about 50 years. The latter fires would be of a lower intensity than the former, of course.

4.3 Mountain Ash

Mountain ash is a eucalypt that is relatively easily killed by fire. This is not to say that the intensity necessary to kill the trees is low (Gill, Lang and Moore in review.). Indeed, it may exceed the uppermost intensity recognized for the control of forest fires (Luke and McArthur 1978). Trees of this mountain ash can reach 105m in height (Ashton 1975). It appears that, for death to occur, the whole tree crown has to be killed – as shown by browning, or scorch, of the leaves after fire (Gill, Lang and Moore, in review). It is said to be 'relatively fire sensitive' because of this characteristic. Other species, like Messmate, will usually resprout after all the leaves are killed; it is more tolerant. Death of all the leaves on the mountain ash is an indicator of the death of the tree, probably not the cause; it indicates that the regenerative buds in leaf axils, in the upper branches, and in the bark of the trunk above the 'skirt' on the bole, have been killed.

When the tree dies, there is a massive seed drop from capsules stored in the tree crowns (Ashton 1979). This massive seed drop becomes the food for seed eating ants but, as this is incomplete, the remaining seeds germinate and form the basis for a new generation of trees (Ashton 1979). Over 2 million seedlings per hectare may result (Ashton 1976a). A new cycle of life has begun.

A curious feature of the mountain ash forest is that fires appear to be necessary for the perpetuation of the forest but they can also destroy it. Without fire, the eucalypt seeds that trickle to the ground through the dense understorey find the conditions of litter, shade, browsing and fungal infection (Ashton and Macauley 1972, Ashton and Willis 1982), let alone predation by ants (Ashton 1979) too great and all the eucalypt seedlings die.

Because the only source of regeneration after death of trees is seed on the plant, there is potential for trees that have not yet reached maturity to be killed and the species to be locally eliminated (Ashton 1981). This happened when fires were at intervals of 15-20 years (Ashton 1981). If the trees grow centuries old and die, there is no suitable seed bed for regeneration and again the species is locally eliminated (Ashton 1981).

Fires at the right intervals and with the appropriate intensities will clear the forest floor for regeneration, allow the abundance of seed to germinate and seedlings to grow in the nutrient and light enriched substrate (Ashton 1981).

4.4 Leadbeaters Possum

Leadbeaters possum is a small possum (130g) that lives in hollows of living and dead trees (Smith 1984, Lindenmayer 1996). The species was thought to be extinct in 1961 but it was then rediscovered in Central Victoria by an enthusiastic amateur (see Smith 1984). It is a potent symbol for conservationists in Victoria.

The hollows in which the possum lives begin to form in mountain ash trees when they are nearing 200 years of age (Lindenmayer 1996). This is longer than the fire cycle mentioned above. Thus for the species to persist, the cycle has to be longer than 200 years or there has to be some random variation about the 100-year average for tree-killing fires (McCarthy *et al.* in press).

4.5 Other Species

There are many species of plants and animals, especially the fungi and insects that have unknown responses to fire regimes. Insects are causing dieback in some places. Fungi in the form of mycorrhizae assist in the growth of many species of plants (Ashton 1976b). Ashton's (1976b) research implicated at least 18 different basidiomycetes in mycorrhizal formation but ascomycetes appear to be a feature of early succession (Warcup 1991).

Some of the vascular plants have well known responses to single fires and these serve to make the point that, in the one ecosystem under the one fire regime, there are a variety of responses among the plants and animals. Thus, while the mountain ash is regarded as relatively sensitive and has seeds stored in the canopy and none in the soil – perhaps uniquely so in this ecosystem - the small tree, *Pomaderris aspera*, is relatively sensitive but has seeds stored in the soil (Ashton 1981). Another common small tree is *Bedfordia salicina*, a species with populations that readily resprout after fire even when the stem is killed (Ashton 1981). A few species of plants, ephemerals, may appear soon after fire but die out later, probably leaving a legacy in the form of soil-stored seed (Ashton and Martin 1996b). Fire may affect the germination response of these seed. Forty percent of the plant species in Ashton and Martin's (1996a) study resprouted from "rhizomes, corms, roots or lignotubers". Perhaps 30% of resprouters in *E. regnans* forests of Central Victoria are woody Ashton (1981).

Populations of mistletoe that have colonized mountain ash in some places have no viable seed storage after death from fire but they are able to recolonize the new ash population by migration. Migration happens at the behest of the mistletoe bird which is not necessarily affected directly by any fire (by death) but loses a feeding source, the mistletoe fruit. A fire removing the understorey may affect habitat to the extent that it is to the detriment of certain animals until restored.

Two tree-killing fires within 5-8 years will eliminate *Pomaderris aspera* while two tree-killing fires – necessarily of higher intensity - within 15-20 years will eliminate *E. regnans* (Ashton 1981). With a lack of fire, rainforest species may succeed the eucalypt forest (Ashton 1981). There are many possibilities for the species composition of the forests as a result of variation in fire-regimes. The outcomes are dependent on species' cycles of life (and species' intrinsic properties) together with the lengths of cycles of fire (Noble and Slatyer 1981) and fire characteristics.

5 CONCLUSIONS

These communities ..."*were born in fires; ... can survive only with fires; ... are dying today because of fires*."

Dr Frank E Egler (1952) [referring to the Everglades of southeastern United States, could equally well have been talking of the Mountain Ash].

The case history reveals that cycles of fire and cycles of life interact in a number of ways. The mountain ash can be eliminated by fires and can be perpetuated by fires. Leadbeaters possum can survive the usual fire interval between tree killing fires only if there is variation about the average interval. Other plants and animals in the mountain ash ecosystem can have different mechanisms of survival and persistence. Some plants resprout, some have seeds stored in the soil. Some 'avoid' direct impingement of fire (*e.g.* because plants are ephemeral, but stored seed in the soil may be affected by fire) while others depend on migration from an external source for recolonization after severe fire (*e.g.* mistletoe). Still others (*e.g.* the Mistletoe Bird) lose a food source or habitat so the fire's immediate effect may be indirect.

The mountain-ash forest example is the result of extensive observation and measurement by professional scientists and, especially in the animal studies, by enthusiastic amateurs. There is a need for competent observers throughout Australia to further our knowledge of the interactions between the cycles of life and the cycles of fire. There are many ways to doing this - from the marking and photographing of plants and plots at chosen times to the recording of tracks of animals and the rational collecting of insects in relation to fire events of known characteristics. From the collated observations of the present can come the theories and generalizations of the future.

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The Impact on the Environment – The Atmosphere

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ABSTRACT

There are two major atmospheric concerns in relation to bushfires. Firstly, their role in generating air pollution. Secondly, their role in altering the carbon balance of the atmosphere and thus contributing to climate change and possible global warming.

Air pollution consequences primarily arise from the smoke generated from bushfires, though the generated gases also play a role. For example, prescribed burning of grasslands and forests has been estimated to be the largest source of dioxin emissions in Australia. Smoke effects relate to lack of visibility, and to health effects from the particulate matter within the smoke. The visibility and health effects depend on the composition of the particulate matter in the plume, and the location of the plume in relation to urban areas.

The consequences of climate change and possible global warming are extensive and include the possibility of greater numbers of bushfires in Australia. Australia has adopted agreed inventory methods to estimate the greenhouse gas emissions as a result of grassland and forest fires. The Framework Convention on Climate Change (FCCC) limits itself to anthropogenic emissions to the atmosphere. Hazard reduction burns, which are deliberately lit, are anthropogenic. Though currently accounted in the National Greenhouse Gas Inventory, the following question remains under review: should uncontrolled bushfires, which may or may not have been deliberately lit, be treated as anthropogenic or as natural? Thus, even though hazard reduction burns are preferable to infrequent but destructive conflagration, air pollution control regulations make it more difficult to conduct such burns.

There are two sources of tension resulting from hazard reduction burning. The first of these is the high probability that smoke emissions will breach air quality pollution guidelines and be injurious to human health. The second of these is that the greenhouse gas emissions from the fires increase Australia's emissions under the FCCC. Both cases require a risk-benefit analysis in which the risks associated with uncontrolled conflagrations have to be compared to the social benefit of hazard reduction burning. This paper details the nature of these tensions and concludes that public tolerance of prescribed burning will decrease as there is greater public knowledge of the detrimental health effects to the public from particulate matter, and to firefighters from possible dioxin inhalation. Nevertheless, there are sufficient uncertainties associated with both effects that measurements are needed to test the risk analysis.

INTRODUCTION

A bushfire consists of a combustion process in which plant fuels ignite and burn. The basic fuels with which we are concerned are the leaves, twigs, bark and small branch wood in forest and also the fine fuels found in grassland. All of these are chemically similar and consist mainly of complex compounds containing the plant macro-nutrients, carbon, hydrogen, oxygen, nitrogen, phosphorous, sulfur, potassium, calcium, and magnesium together with chlorine and sodium. Although proportions vary considerably, these fuels contain, in terms of dry weight, about 50% carbon, 40% oxygen, 6% hydrogen and up to 2% nitrogen. They also contain about 4% inorganic cations, which remain as the familiar white ash of hot fires. The prerequisites for this reaction to proceed are high temperatures (350 to 900°C) and an ample supply of oxygen. The principal products are carbon dioxide and water vapour, together with a large amount of heat energy.

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Plant material consists principally of cellulose. It also contains many other substances, which react to the application of heat in various ways. In many tree and shrub species, resins, volatile oils and waxes are present and add considerably to the flammability of the available fuel, especially the living foliage. Though small in quantity when compared to the total fuel complex, these compounds often ignite readily. By heating other fuel particles, they sustain burning in slightly damp forest litter, or partly green grass, which would otherwise be barely flammable (Luke & McArthur, 1978).

The control of bushfires is different to the control of industrial fires. Bushfires arise from a range of causes, including natural ignition, arson, and fires lit for vegetation and forest management purposes. This last class includes windrow burning, regeneration burning, slash disposal burning, and hazard reduction burning. These different classes can be lumped under the general heading of prescribed burning. Prescribed fires are conducted within the limits of a fire plan and prescription that describes both the acceptable range of weather, moisture, fuel and fire behaviour variables, and the ignition method to achieve the desired effects.

Emissions from bushfires consist of particles and gases. The focus of this paper centres on two aspects of fires. One is the air pollution from toxic gases and from particles, which manifest themselves as smoke. Both gases and particles have direct implications for human health. The second focus is that of greenhouse gas emissions. During combustion, carbon dioxide, methane, nitrous oxide and other greenhouse gases are emitted. These gases may alter the radiation balance of the atmosphere and thus contribute to possible climate change and global warming. The aerosols emitted from fires may have the opposite effect and act to reduce global warming.

1 AIR POLLUTION

1.1 Background

The major air pollution concerns arising from bushfires are as follows:

a) There is persistent epidemiological evidence that there are increased respiratory symptoms, and increased mortality, at times of increased particulate matter. The topic is reviewed by Lipfert (1994), Wilson & Spengler (1996) and, within an Australian context, by NEPC (1998). The topic is contentious (Abramson & Beer, 1998) primarily because no plausible biological mechanism has yet been found to explain the association between short-term effects and particulate matter.
b) Combustion products contain known carcinogens, the best-known of which are benzo-pyrenes (Committee on Risk Assessment of Hazardous Air Pollutants, 1994: Appendix H-2).
c) Combustion of natural Australian fuels emits both oxides of nitrogen, and hydrocarbons. These materials are precursors to the formation of ozone, which is a major constituent of photochemical smog. This is a major topic in its own right and will not be dealt with in this paper.
d) Estimates of dioxin emissions from Australian bushfires indicate that prescribed burning and wild bushfires are potentially the largest sources of dioxin into the Australian atmosphere (EPG, 1998).
e) Bushfire smoke reduces visibility. Thus, if bushfire smoke drifts onto highways there exists the possibility of increased automobile accidents.

1.2 The Production Of Toxic Substances

Smoke from prescribed fires is a complex mixture of carbon, tars, liquids, and different gases (including carbon monoxide, aldehydes, nitrogen oxides, peroxides, acids and products specific to the combustion of chlorine-containing or nitrogen-containing polymers). The solid and liquid phases may contain carcinogens, irritants, and trace metals. Smoke toxic materials may be dissolved in liquid droplets, or absorbed at the solid-gas or liquid-gas interfaces (Ward & Hardy, 1991; Andreae et al., 1996).

Nitric oxide, NO, produced by a reaction between fuel nitrogen and oxygen in the air, is a free radical (it contains an unpaired electron). Because NO production rate is a function of flame temperature, the temperature of the flame will determine the efficiency of the hydrocarbon chain reaction and the amount of nitrogen incorporated into the product of combustion process.

1.2.1 Carcinogens

The most toxic materials found in the aerosol portion of the smoke are probably carcinogens and toxic trace metals. This toxicity refers to long-term exposures. Carcinogens are substances that produce cancer upon application to the skin, or inhalation into lungs. They may be polycyclic organic material such as benzo-pyrene, which is a condensed five-ring system found in many combustion products (Committee on Risk Assessment of Hazardous Air Pollutants, 1994: Appendix H-2).

1.2.2 Dioxins and Furans

For the purposes of this analysis we take a dioxin to be any compound containing the dibenzo-p-dioxin nucleus, and we only consider that sub-set of furans that contain the dibenzofuran nucleus. Environmental concerns are directed at the chlorinated species, rather than dioxins and furans containing other halogens. These concerns relate to the variety of cancers that arise from exposure to low concentrations of dioxins and furans. Acute exposure to dioxins and furans can lead to chloracne disease, and a variety of symptoms that include eye and respiratory tract irritation, personality changes, nausea, severe muscular aches, emotional instability and sleep disturbances (EPG, 1998).
It is found that the dominant contribution is from prescribed burning and from wildfires. Table 1 summarises the top ten sources of dioxin and furan emissions (EPG, 1998).

Source and Rank	Emission factor (μg/tonne)	Activity data (ktonnes/year)	Emission (g/year)
1. Prescribed burning			65-1300
- agriculture & forest	0.5-10	6800	3.4-68
- grasslands	0.5-10	124000	62-1240
2. Bushfires	0.5-28	14300	7-400
3. Cement clinker*	0.02-25	6140	0.12-153
4. Residential wood combustion			15-98
- clean wood in stoves	1-3	2300	2.3-7
- treated wood in stoves	10-50	400	4-20
- clean wood in fireplaces	1-29	1230	1.2-36
- treated wood in fireplaces	100-500	70	7-35
5. Coal combustion			4.5-73
- Industrial coal	0.04-4.8	10000	0.4-48
- Utility coal	0.060-0.35	70000	4.2-24.5

* The Cement Industry Association is presently re-assessing these figures.

Table 1: Estimates of Australian emissions of dioxins and furans for 1994.

The emission factors for dioxins and furans are based on USA, UK and the Netherlands studies. There are no Australian data. The lower limits of 0.5 μg/tonne of fuel (on a dry-weight basis) are based on the US work, which examined wood burning in open fireplaces. The value of 10 μg/tonne for the upper range of prescribed burning is based on the Netherlands work and appears to be the average of an estimate of emissions from agricultural burning (4 μg/tonne) and from residential wood burning (16 μg/tonne, as a representative value). Both the Netherlands and the UK work reported values of 28.5 μg/tonne as the highest values observed in the combustion of clean wood in residential fireplaces. This value has been used as the upper bound on the emission factor for both bushfires and for untreated wood in fireplaces.

Are these overseas results relevant to Australia? Dioxins have been detected at elevated concentrations in soils from agricultural areas in Northern Queensland (Müller et al., 1996) as well as in the urban air of Brisbane (Müller et al., 1998). There appear to be missing sources in dioxin inventories (Thomas & Spiro, 1996). It remains unclear whether forest and agricultural fires generate the dioxins and furans – possibly because of salt accumulation in coastal areas – or whether the fires release previous accumulations of anthropogenic dioxins (Brzuzy & Hites, 1996).

There is thus a need for a series of experiments measuring dioxin emissions in Australian fires. The first reason for this is that such experiments could be used to derive Australian emission factors for dioxins and furans. The second reason is to test the dioxin generating mechanism. If dioxins arise from salt accumulation then near the coast, where one can expect salt accumulation, forest and grass fires would have higher dioxin concentrations than those in inland regions, where salt accumulations would be less.

1.2.3 Trace metals

Trace metals and their compounds, such as mercury, lead and cadmium, may be highly toxic in aerosol form. The National Environment Protection Measure for Ambient Air Quality (NEPC, 1998) provides an air quality standard for lead in the atmosphere and also for particulate matter of diameter less than 10 µm in diameter, known as PM10. The standard for lead requires the concentration, based on a one-year average, to be less than 0.5 $\mu g/m^3$. The PM10 standard requires the concentration, based on a one-day average, to be less than 50 $\mu g/m^3$.

Regulatory attention is focussed on small particles because the lung retention of aerosols is related to the particle size (Streeton, 1997). Maximum retention occurs in the range of 0.4 to 0.5 µm. The incorporation of trace metal species in particles of respirable size greatly increases the toxicity of such aerosols. Small particles are also of concern because they settle-out more slowly than large particles, thus small particles are transported greater distances by the ambient winds.

1.2.4 Smoke generation

The generation of smoke is the direct result of the combustion process. For that reason, the meteorological factors that directly influence combustion will also have important effects on smoke generation. The primary meteorological elements that appear to be involved in smoke generation are those that govern fuel moisture and the burning conditions.

At a conceptual level, a bushfire may be envisaged as the complete combustion of a molecule of cellulose as expressed by the following reaction:

$$C_6H_{10}O_5 + 6O_2 \rightarrow 6CO_2 + 5H_2O + \text{heat}$$

In natural fires, because the oxygen (O_2) supply is never sufficient, there is incomplete combustion. This leads to the formation of incompletely oxidised compounds (carbon monoxide, or CO), or reduced compounds such as methane (CH_4), non-methane volatile organic compounds (NMVOC), and ammonia (NH_3), among others.

The emission ratio, explained in the next paragraph, and its variability are critical for any estimate of compound emissions from biomass burning at local, regional, or global levels. The emission ratio is highly dependent on the type of combustion, especially the relative importance of the two main phases of the combustion, flaming and smouldering. Whatever the combustion phase, the main compound emitted is CO_2, which represents between 85% and 90% of the carbon (C) released into the atmosphere (Lobert et al., 1991; Ward & Hardy, 1991).

The calculation of gaseous or particulate trace compound emissions from biomass burning is based on the concepts of emission ratio and emission factor (Delmas et al., 1995). These concepts are necessary because absolute concentrations in smoke plumes represent only the degree of dilution of combustion products in ambient air. The emissions from biomass burning are proportional to the amount of dry matter actually burned (M), and to the emission factor of each compound, which represents the quantity emitted per unit of dry matter burned. This factor is generally expressed in g/kg of dry matter burned. Thus

$$\text{Emissions} = F\,M$$

where F is the emission factor.

Ward & Hardy (1991) define the combustion efficiency (E) of a wildfire and relate emission factors to this efficiency. The combustion efficiency is the molar ratio of the carbon dioxide emitted to the total carbon-containing gases, namely CO_2, CO and CH_4. They obtain emission factors (F) as

Particulate Matter: $F = 93.3 - 90.5\,E$

PM2.5: $F = 67.4 - 66.8\,E$

where PM2.5 represents particles of diameter less than 2.5 µm, and F is expressed in units of grams of particulate matter per kilogram of fuel burnt. These results indicate that PM2.5 ranges from 72% of the particulate matter for low efficiency fires, to 21% for high efficiency fires.

1.2.5 Smoke particle size

Some early reports on the size of forestry smoke particulate matter erroneously indicated a particle size range from 50 to 100 µm in diameter based on the examination of microscopic slides placed downwind from the fire. The particles examined were primarily partially consumed fuel fragments and ash particles. Such large particles, which Lee (1988) calls smut, are produced primarily by high-intensity fires when the turbulent convective activity in the fire zone is sufficient to mechanically generate and entrain large particles in the smoke column. Because of their large size they rapidly fall-out relatively close to the fire.

Radke et al. (1991) measured the volumetric concentrations as a function of particle size fraction for particulate matter released from prescribed fires of logging slash in the western United States. The relationship consisted of a bi-modal distribution with a peak at about 0.2 µm, an absence of particles of about 1 µm size, and then an increasing concentration of particles in the larger size fractions. This general form of the particle size fraction curve has been reproduced on numerous occasions and illustrates the reasons for the health concerns in relation to bushfire smoke. Most of the particles are within the size range at which maximum lung retention occurs.

1.2.6 Visibility relationships

The effect of smoke on visibility depends not only on the concentration of particles emitted, but on the optical properties of the particles as they affect the scattering, absorption, and total extinction of light. Tangren (1982) reviewed a number of studies that reported the relationship between the mass of forest fire particulate matter and light scattering properties. The colour of forest fire smoke can vary from dark black, through various shades of grey, to pure white. Black smoke will predominate during vigorous flaming combustion, especially when burning foliage fuels containing a high percentage of extractable hydrocarbons. As flaming combustion diminishes, tarry droplets from smouldering combustion begin to predominate and the smoke colour changes from black to white. On a volume, number, and mass basis, the tarry droplets usually predominate over the solid black soot particles. Soot particles scatter as well as absorb light. This double effect gives soot particles an influence on visibility greater than their atmospheric concentration would suggest. Also, the soot particles, although chemically inert, carry reactive groups on their surface that take part in important atmospheric reactions. Gras et al. (1999) examined the optical properties of smoke aerosols in Indonesia and Tropical Australia, and found an increase in the scattering, as the relative humidity increases, that is due to many smoke particles being hygroscopic.

1.3 Modelling Bushfire Smoke

Beer (1992) combined representative emission rates and plume rise equations to estimate expected ground level concentrations of particulate matter for different types of controlled burning strategies at different downwind distances and different wind speeds. His results are shown in Figures 1 and 2, which depict the calculated ground level concentrations of particles from a fire management operation that could be conducted either as 25 equally spaced point ignitions, or as a line fire. A total suspended particle concentration of 200 µg / m^3 is also shown in these figures, as a horizontal line, corresponding to a concentration of 2×10^{-7} kg / m^3 . This is taken to be approximately equivalent to a PM10 concentration of 50 µg / m^3 on the assumption that there is a substantial smut component so that the PM10 is only about 25% of the total particles.

The air pollution considerations in the two cases of point and line ignition are very different, with line fires generally producing lower air pollution. The highest values of maximum ground level concentration occur when the smoke plume is close to the ground. The maximum ground level concentration from a backing fire is significantly greater than from the heading fire associated with the same ignition. These figures illustrate that the air pollution potential from large-scale area burning is very sensitive to maintenance of the prescribed conditions. For example, the ground level concentration from the backing line fire remains below specified values for the wind speeds in the range of the prescription (3 m/s to 5 m/s). A sudden increase in wind speed to 10 m/s, or greater, will result in values that exceed air pollution standards.

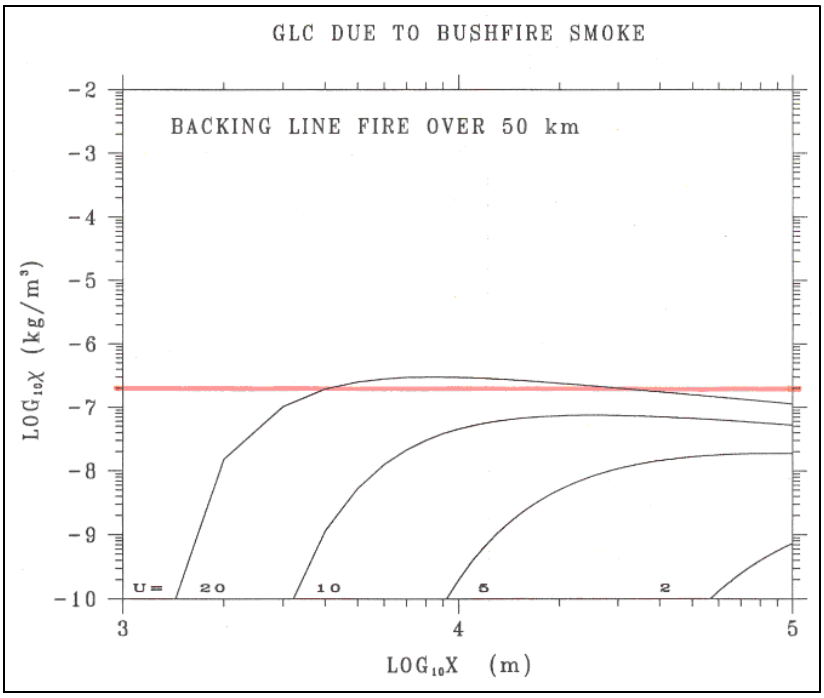

Figure 1: Predicted centre-line ground level concentrations of total suspended particulate matter for a backing line fire over 50 km as a function of downwind distance and wind speed (in m/s). It is assumed that in the absence of wind the rate of spread of the fire would be 1 mm/s. The solid line depicts a suspended particle concentration of 200 μg/m3.

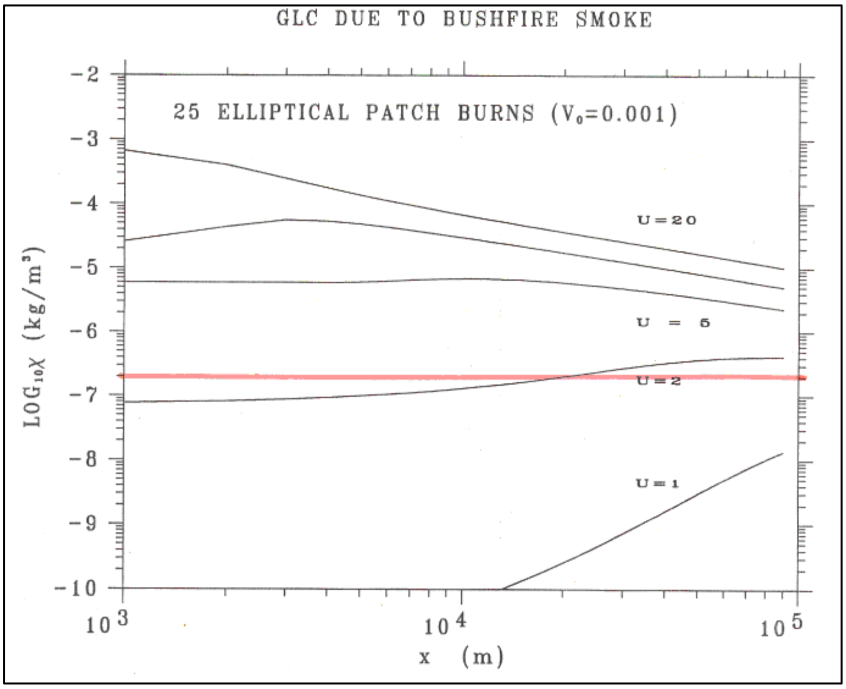

Figure 2: Predicted centre-line ground level concentrations for 25 elliptical fires covering a 2500 km² area for the same distances and wind speeds as in Figure 1.

2 CLIMATE CHANGE

The consequences of climate change and possible global warming are extensive and include the possibility of greater numbers of bushfires in Australia (Beer & Williams, 1995). Australia has adopted agreed inventory methods to estimate the greenhouse gas emissions as a result of grassland and forest fires. The Framework Convention on Climate Change (FCCC) limits itself to anthropogenic emissions to the atmosphere. Hazard reduction burns, which are deliberately lit, are anthropogenic. Though currently accounted in the National Greenhouse Gas Inventory, the following question remains under review: should uncontrolled bushfires, which may or may not have been deliberately lit, be treated as anthropogenic or as natural? Thus, even though hazard reduction burns are preferable to infrequent but destructive conflagration, air pollution regulations make it more difficult to conduct such burns.

There are two sources of tension resulting from hazard reduction burning. The first of these is the high probability that smoke emissions will breach air quality pollution guidelines. The second of these is that the greenhouse gas emissions from the fires increase Australia's emissions under the FCCC. Both cases require a risk-benefit analysis in which the risks associated with uncontrolled conflagrations have to be compared to the social benefit of hazard reduction burning. This paper undertakes this risk assessment from an atmospheric perspective.

2.1 Greenhouse Gas Inventories

Australia is a signatory to the United Nations Framework Convention on Climate Change (FCCC) (see http://www.unfccc.de/resource/convkp.html) whose objective, as stated in Article 2, is to achieve stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Article 4.1 and Article 12.1 of the FCCC require the parties to the convention to periodically publish:

> "national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal protocol, using comparable methodologies to be agreed-upon by the Conference of the Parties."

To assist countries to meet this obligation, the IPCC (1996) has produced national guidelines for preparing inventories including an internationally agreed default methodology and provides documentation, workbooks, and software to support the IPCC methodology. The IPCC also encourages nations to develop their own methodologies where these will be more accurate than the default methodology. Certain countries, such as Australia, have developed alternative methodologies because of their unique condition. In Australia's case there is a large greenhouse gas contribution from landuse change and from fires that are not adequately dealt with in the IPCC default methodology.

Greenhouse gas inventory methodologies use an accounting basis such that at the simplest level:

Greenhouse Gas Emission = Activity x Emission Factor

where the emission factor is a term that relates the emission of a particular greenhouse gas to the activity that generates the gas.

Greenhouse gas workbooks provide information on likely sources, and representative values of emission factors. These are provided for the relevant greenhouse gases of interest which, on the basis of the Kyoto Protocol, are:

- Carbon dioxide;
- Methane;
- Nitrous oxide;
- Chlorofluorocarbons and perfluorocarbons;
- Sulfur hexafluoride.

The IPCC guidelines also encourage nations to estimate the emissions of ozone precursor gases such as CO, NMVOC and NOx.

The international guidelines for National Greenhouse Gas Inventories have three sections that deal with fire. In the Agriculture module there are step-by-step instructions for calculating emissions from i) prescribed burning of savannas, ii) field burning of agricultural residues, and within the Landuse Change & Forestry module there are instructions on how to deal with iii) on-site burning of forests. The key concept in these inventories is that the nett CO_2 emissions from agricultural burning are zero. The reason for this is that, even though the burning results in instantaneous emissions of carbon dioxide, vegetation regrows between the burning cycles. During vegetation regrowth the CO_2 is reabsorbed so that the nett emissions from the cycle are zero. However, CO_2 emissions from the permanent conversion of forests and grassland to cropland or pasture are counted.

The assumption that the emitted CO_2 is re-assimilated within a year is a first approximation. It assumes that the ecosystems remain in equilibrium. This may not be true if fire frequency or climate change leads to changes in ecosystem structure.

Burning also releases gases other than CO_2 including methane, carbon monoxide, nitrous oxide and other oxides of nitrogen. Unlike agricultural CO_2 these are treated as nett anthropogenic emissions and counted in the inventories.

The revised 1996 IPCC guidelines do not deal with forest fires. The Australian methodology dealing with non-carbon dioxide gases from the biosphere (National Greenhouse Gas Inventory Committee, 1996b) notes that:

> "Burning is carried out in Australia either anthropogenically or as a result of wildfires. The anthropogenic burning occurs for a variety of reasons including fuel reduction, prevention of uncontrollable wildfires, and traditional Aboriginal burning. These anthropogenic fires replace wildfires that would occur naturally otherwise, albeit at other times of the year. Anthropogenic fires probably have occurred in Australian ecosystems since at least 38000 BP (Singh et al. 1981).
>
> It should not be assumed that stopping anthropogenic fires would lead to a reduction in greenhouse gas emissions, because they would be replaced by natural wildfires. In many cases it is impossible to determine whether a fire has been deliberately lit or is the result of a natural ignition process such as a lightning strike. Until the appropriate anthropogenic component of these emissions can be distinguished, all fires in Australian forests…[are included]… The IPCC Methodology for emissions associated with forest burning needs further consideration in the light of this discussion."

To date, all Australian national greenhouse gas inventories have been compiled using the Australian methodology and account for emissions from prescribed fires and wildfires in forests.

2.1.1 Quantifying Australian emissions

Tolhurst (1994) provides quantitative estimates of the area burnt, the fuel loads and the burning efficiency of prescribed burns and bushfires. Large year-to-year variations in biomass burning occur because of climatic variability. Greenhouse gas emissions from bushfires are therefore calculated on the basis of a 10-year average of the areas burnt.

Table 2 collates the estimates (National Greenhouse Gas Inventory Committee, 1996a) of Australian non-CO_2 greenhouse gas emissions from prescribed burning and from wildfires. These values are based on 10-year running means of the estimates of the individual years, which have not hitherto been available and are thus given in Appendix 1 for wildfires, grass fires, and prescribed burning. The tables in Appendix 1 also calculate annual CO_2-equivalents, on the basis of the global warming potentials (GWP) given in Table 2. Presently, direct CO_2 from biomass burning is not included in inventory calculations because of the assumption that today's emissions are balanced by future growth. If future inventory guidelines vary this assumption then the CO_2 from fires will form an important component of the Australian inventory.

The Australian Greenhouse Gas Inventories list the values in Table 2 as "Prescribed Burning of Savanna and Temperate Grasslands", but this wording was chosen to maintain compatibility with international guidelines. The values in Table 2(b) refer to all grass fires. These values are converted into CO_2-equivalents by multiplying the gas emissions in Table 2 by 100-year global warming potentials (GWP) as given in parentheses. The global warming potentials of the indirect greenhouse gases (NO_x, CO and

NMVOC) are taken to be zero because they are the subject of continuing research, and the current IPCC convention is thus to exclude these gases when calculating CO_2-equivalents. The CO_2-equivalent values for 1990 are 11,097 Gg, 336 Gg and 1,313 Gg for grassland prescribed burning, forestry prescribed burning, and wild bushfires respectively. For comparison, the 1990 Australian inventory yielded total agricultural emissions of 100,793 Gg CO_2-equivalent and total emissions from land use change and forestry of 131,082 Gg CO_2-equivalent of which 9,414 Gg CO_2-equivalent was from CH_4 and N_2O. As a very rough approximation we may note that 15% of the non-CO_2 emissions in each sector arise from burning.

(a)

	Wheat, grain and sugar cane burning					
Gas (GWP)	CH_4 (21)	N_2O (310)	NOx	CO	NM-VOC	CO_2-equiv.
1988	7.59	0.22	13.64	298.6	17.42	228
1989	7.3	0.2	13.1	287.6	16.9	215
1990	7.3	0.24	12.5	288.2	16.8	228
1991	7.2	0.2	12.4	281.9	16.5	213
1992	6.5	0.2	11.7	253.9	14.9	199
1993	6.1	0.2	11.9	240.4	14.1	190
1994	5.4	0.1	11	208.3	12.2	144

(b)

	Grass fires					
Gas (GWP)	CH_4 (21)	N_2O (310)	NOx	CO	NM-VOC	CO_2-equiv.
1988	304	15.6	904.1	11888	696.5	11220
1989	302	15.5	896.3	11788	690	11147
1990	301.1	15.4	893.7	11753	688.6	11097
1991	299.1	15.3	887.9	11677	684.1	11024
1992	276.9	14.19	821.9	10810	633.3	10214
1993	276.2	14.16	819.7	10781	631.6	10190
1994	265.7	13.6	789	10375	608	9796

(c)

	Prescribed burning (forests)					
Gas (GWP)	CH_4 (21)	N_2O (310)	NOx	CO	NM-VOC	CO_2-equiv.
1988	12.1	0.22	9.1	355.8	43.2	322
1989	12.3	0.23	9.3	362.5	44	330
1990	12.6	0.23	9.5	370.6	45.0	336
1991	12.5	0.23	9.4	368.4	44.7	334
1992	12.7	0.23	9.6	374.2	45.4	338
1993	12.9	0.24	9.8	383.1	46.5	345
1994	13.0	0.24	9.8	385	46.6	347

(d)

	Wildfires					
Gas (GWP)	CH_4 (21)	N_2O (310)	NOx	CO	NM-VOC	CO_2-equiv.
1988	36	0.67	27.2	1063.3	129.1	964
1989	36.5	0.68	27.6	1079	131	977
1990	49.1	0.91	37.1	1449	176	1313
1991	51.4	1.0	38.8	1516.4	184	1389
1992	48.3	0.89	36.5	1425.2	173	1290
1993	47.3	0.87	35.8	1397.2	169.6	1263
1994	47.2	0.9	35.7	1394	169.2	1270

Table 2: Greenhouse gas emissions (Gg) from burning in Australia. The 100 year global warming potentials (GWP) used to convert the gases to CO_2-equivalents are given in parentheses.

2.1.2 Discussion

There is an active debate in the literature, which is relevant to Australia, about distinguishing "anthropogenic" from "natural" activities in forestry (Winiwarter et al., 1999). If wildfires cease to be considered as "anthropogenic" within the Australian greenhouse gas inventories, then the greenhouse gas emissions attributed to Australia will decrease. Whether such an attribution is legitimate depends on the ignition source of wildfires. Australian fire authorities attribute the preponderance of wildfire ignitions to human causes. Very few are the result of lightning.

2.2 Aerosols

The scattering and absorbing particles that constitute smoke modify the transfer of radiative energy in the atmosphere so that the solar energy reaching the ground level is reduced. This phenomenon, namely the cooling that arises when large amounts of smoke are injected into the atmosphere, has become known as the nuclear winter hypothesis (Pittock et al., 1986). Robock (1988, 1991) has shown that the surface temperatures were reduced between 1.5^{o}C and 4^{o}C during daytime over North America under the extended smoke plume from a large forest fire in British Columbia. Modelling of this event (Westphal et al., 1989) has shown a heating rate of about 2^{o}C per day in the mid-troposphere due to the smoke absorption. The smoke particles had a lesser influence on the longwave radiation, which means that no change in the night-time surface temperatures was observed in this particular event.

2.3 Fire-Climate Feedback

Beer et al. (1988), Beer & Williams (1995) and Cary (in press) have examined bushfires in Australia under a changed climatic regime. Their results, based on the use of fire danger indices, indicate an expectation that there will be more fires. Goldammer and Price (1998) investigated changes in lightning occurrence to predict the likely changes in fire regimes. They reported that the modelled frequency of lightning increased over all continental areas and doubled over most of Australia for a doubled CO_2 climate simulation.

3 RISK MANAGEMENT

Australia and New Zealand have jointly developed a risk management standard (Standards Australia and Standards New Zealand, 1999). The standard is designed to provide a consistent vocabulary and to assist risk managers by delineating risk management as a four step process that involves risk identification, risk analysis, risk evaluation and risk treatment. Beer and Ziolkowski (1995) specifically examined environmental risk management and produced a framework (Norton et al., 1996) known as the 7Cs of environmental risk management. This name is used because each activity to be undertaken within a risk management exercise begins with the letter C.

The two approaches may be combined diagrammatically, as shown in Fig. 3. The text outside of the diamond refers to the nomenclature of the Australian and New Zealand Standard. In addition to the four steps described above, there are overarching concepts. These constitute determining the context of the exercise, setting criteria against which subsequent evaluation will take place, ongoing monitoring and review, and ongoing consultation.

The circle shows the activities of the 7Cs. Risk identification consists of determining concerns and their consequences. Risk analysis is the process of calculating the consequences and their associated likelihoods (shown as certainties and uncertainties). Risk evaluation compares the calculations against the pre-determined criteria, and risk treatment is a process of control and risk communication.

The vertices of the diamond are used for terms that encompass two of the risk management steps. Risk appraisal is the process of identifying and analysing risk. Risk assessment, in Australia and New Zealand, is used as the process of analysing and evaluating risk. Risk characterisation evaluates and treats the risk. Finally, the mnemonic "Act" is used to mark the vertex linking treatment and identification.

The Australian debate on the merits (or otherwise) of prescribed burning has been mainly based on ecological arguments (Gill et al., 1981) with no consideration of air pollution or climate change issues. In America, Pyne (1991) points out that the views oscillate on about a 20 year-cycle. This section of the paper will examine the atmospheric considerations within a risk-based context, applying the 7Cs.

3.1 Concerns

The particular concern that we wish to address relates to prescribed burning. Should it, or should it not, take place?

3.2 Consequences

Air pollution consequences primarily arise from the smoke generated from bushfires though the generated gases also play a role. Smoke effects relate to lack of visibility, which affects transport, and to health effects arising from the particulate matter within the smoke.

Under the present Australian greenhouse gas inventory methodology, the consequences to the atmosphere of emitting greenhouse gases from wildfires is the same as the consequences of emitting greenhouse gases from prescribed burns. But the present rules are based on a particular understanding of the meaning of 'anthropogenic' according to which all bushfires are treated as anthropogenic, and their emissions tabulated for national inventory purposes.

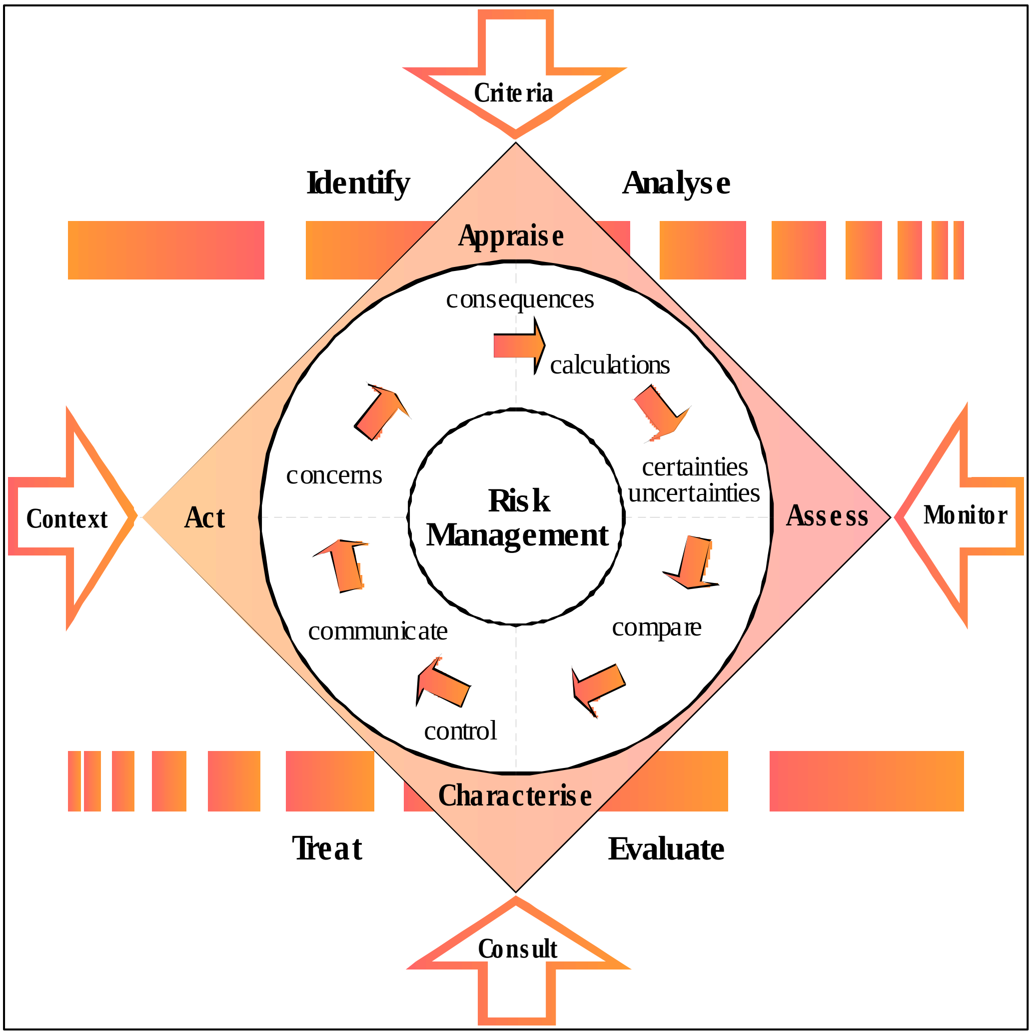

Figure 3: This diagram links the nomenclature of risk management given in the Australian & New Zealand Standard (outside the diamond) with the activities needed to conduct an environmental risk management exercise (inside the circle). The quadrants of the circle relate to the terms in the Standard. There are also some terms, in the vertices of the diamond, that encompass two of the quadrants.

At present CO_2 is not included but there are arguments that within the Landuse Change and Forestry sector of the inventories, emissions of greenhouse gases should be based on changes in carbon stocks. This approach would include effects of bushfires, which result in nett emissions of CO_2.

3.3 Calculations

The National Environment Protection Measure (NEPM) for Ambient Air Quality (NEPC, 1998) provides a standard of 50 µg m^{-3} for particulate matter of less than 10 µm in diameter (known as PM10). The goal of the NEPM is to limit exceedances of this standard to no more than five per year. There is epidemiological evidence that an increase of 10 µg m^{-3} in PM10 produces a 1% increase in the mortality rate (Ostro, 1993; Streeton, 1997; NEPC, 1998). This underpins the desire to ensure that any smoke plume from a prescribed fire does not impinge on human settlements. Mesoscale meteorological models can be used to determine the direction and extent of smoke plumes. The visibility and health effects depend on the composition of the particulate matter in the plume, and the location of the plume in relation to highways and urban areas.

The calculations for the concentrations of particles in smoke plumes, given in Figures 1 and 2, can also be used to obtain rough estimates of dioxin concentrations and dioxin dose. These curves of expected atmospheric concentrations were based on an assumed emission of 10 kg of smoke per tonne of fuel. We have already noted that overseas studies of dioxin emission are based on 10 µg of dioxin per tonne of fuel. Thus, as a first approximation, one may estimate dioxin concentrations as 10^{-9} of atmospheric particle concentrations. For example, the concentrations from patch burns at a wind speed of 5 m s^{-1} are about 6000 µg m^{-3} , which equates to about 6 pg m^{-3} mass of dioxin in volume of air. In the absence of further information we will take this to be a representative upper bound for the dioxin concentration in the smoke from a prescribed burn.

3.4 Certainties and Uncertainties

The probabilistic nature of a risk assessment of the issue arises because wildfires occur at irregular time intervals. Controlled burns, by contrast, can be set by prescription up to five times per year, as we have seen, but we may expect this figure to reduce. The draft version of the NEPM for Ambient Air Quality permitted only one exceedance per year of the PM10 standard. The one exceedance was increased to five exceedances at the specific request of the bushfire control authorities, who argued that prescribed burning operations would be severely hampered if they were effectively limited to one day per year. Without allowable exceedances there would be no window of opportunity during which hazard reduction burning could take place.

The health concerns during prescribed burning and wildfires relate to the particles in the smoke and the other organic compounds. However, the concentrations of most compounds in bushfire smoke, and the likely exposure of firefighters and members of the public, have not been sufficiently studied to enable us to conduct a full quantitative risk assessment.

3.5 Comparison With Criteria

Experts from the World Health Organisation (WHO) have established a tolerable daily intake (over a lifetime) of 1 to 4 pg dioxin (as tetrachlorodibezo-p-dioxin, or TCDD, which is the dioxin for which there is strong evidence of carcinogenicity in humans) per kilogram of body weight. A 70 kg fire-fighter breathing at a rate of 1 litre per second working in smoke containing 6 pg m^{-3} would intake 22 pg per hour. Within three to four hours the tolerable daily intake of 70 pg would be exceeded. At the same time, the particulate matter in the smoke would be about 30 times the PM10 concentrations recommended in the NEPM for ambient air quality.

The NEPM for Ambient Air Quality restricts the permissible exceedances of the particulate matter standard to five occasions per year. During these five exceedances, both the particulate matter standard, and the tolerable daily intake of dioxin, would be exceeded.

The exposure to high concentrations of particulate matter is of concern. The concern arises because the epidemiological evidence indicates that respiratory effects occur in the short-term at all concentrations.

In addition, there are long term effects from the carcinogenic nature of combustion products. We have shown that dioxin may be one of these products – depending on the risks ascribed to a few intermittent exceedances of the tolerable daily intake. Though these dioxin effects are only slightly above the presently-agreed tolerable daily intake, there has been a trend to ascribe health effects to ever-lower values of dioxin. In 1990, the WHO was using a tolerable daily intake of 10 pg per kilogram body weight, but by 1998 had recognised that subtle effects occur in the general population at background levels of 2 to 6 pg per kilogram body weight per day (UNEP Chemicals, 1999). Accordingly, we feel that the possible dioxin risks cannot be dismissed.

3.6 Control And Communication

Table 3 consists of a register for the risks associated with the air pollution effects of prescribed burning. Our specific interest relates to the risks associated with prescribed burning, but these need to be compared to the same risks arising from the expected wildfires if controlled burning does not take place. Because these risks are identical in relation to climate change, under the present national inventory rules, we have not produced a risk register for climate change effects.

Risk	Analysis of event		Existing controls	Con-sequence rating	Likelihood rating	Level of risk	Comment
	Con-sequences	Likelihood					
Smoke (PM10) exceedance (Short-term effects)	Medium	High	General public protected by prescription. Firefighters not protected.	Low	Medium	Low	Ground level concentrations in prescribed burns may be greater than that in equivalent bushfires
Smoke (PM10) exceedance (Long term effects)	Medium	High	As above	Medium	Medium	Medium	Main risk is that of litigation in the long term
Dioxin exceedance	Medium	Medium	As above	Medium	Medium	Medium	As above
Exposure to other carcinogens	Medium	High	As above	Medium	Medium	Medium	As above
Visibility reduction leading to car accident	High	Medium	Smoke forecasting	High	Low	Medium	

Table 3: Risk register for the air pollution risks associated with prescribed burning.

In the absence of controls, the risks associated with burning are high. These can be reduced by prescribed burning prescriptions that specifically consider smoke management and ensure that the smoke does not impact on the general public, and that visibility on main roads is not impaired. This reduces the risk to the general public, but the risks to firefighters remain. The main concern relates to the possible litigation arising from this exposure because of the risk of both short-term and long-term health effects arising from exposure to the constituents of the smoke.

The importance of trace gas emissions from fires as part of the chemistry of the background atmosphere is now recognised by atmospheric chemists. However, the risks associated with perturbation of this chemistry by increasing or decreasing the inputs from fires has not been explored.

Considering the contribution of these trace gas emissions to health risk, and the potential risk from climate change, there appears to be a good case for expressing the atmospheric impact of bushfires in terms of risk. There are few benefits to the atmosphere from bushfires. One may possibly argue that temporary cooling due to aerosols and smoke is a benefit as is the possible decrease in global warming as a result of an increased aerosol load. The issues of control and communication are thus familiar ones; improved meteorological and plume forecasts and their dissemination will:

- provide more accurate information on which to base the decision to ignite a hazard reduction burn;
- improve the ability of fire agencies and land managers to develop policies to minimise the effects of smoke transport;
- assist suppression efforts when they are required.

4 CONCLUSION

A risk assessment of the atmospheric effects of bushfires leads us to conclude that public tolerance of prescribed burning will decrease as there is greater public knowledge of the detrimental health effects to the public from particulate matter, and to firefighters from possible dioxin inhalation. Nevertheless, there are sufficient uncertainties associated with both effects that further research is needed. Further work on the health risk associated with particulate pollution is planned for the re-assessment of the NEPM for Ambient Air Quality. There are no plans of which we are aware for a concerted research effort on atmospheric dioxins from prescribed burning.

5 APPENDIX 1 – YEAR BY YEAR VALUES (GG) OF EMISSIONS FROM NON-AGRICULTURAL BIOMASS BURNING.

5.1 Savanna burning

	Total Mass burned	Emission (Gg)					
Year	Gg	CH_4	N_2O	NO_X	CO	NMVOC	CO_2
1983	126,334	270.5	13.9	803.0	10,561.6	618.7	213,083
1984	116,024	248.4	12.7	737.5	9,699.7	568.2	195,694
1985	137,759	295.0	15.1	875.6	11,516.7	674.7	232,354
1986	108,052	231.4	11.9	686.8	9,033.2	529.2	182,247
1987	108,710	232.8	11.9	691.0	9,088.2	532.4	183,358
1988	111,197	238.1	12.2	706.8	9,296.1	544.6	187,552
1989	107,208	229.6	11.8	681.4	8,962.6	525.1	180,824
1990	108,210	231.7	11.9	687.8	9,046.4	530.0	182,515
1991	111,767	239.3	12.3	710.4	9,343.7	547.4	188,513
1992	107,612	230.4	11.8	684.0	8,996.4	527.0	181,505
1993	86,244	184.7	9.5	548.2	7,210.0	422.4	145,464
1994	160,945	344.6	17.7	1,023.0	13,455.0	788.2	271,460
1995	170,577	365.3	18.7	1,084.2	14,260.3	835.4	287,707
1996	206,482	442.1	22.7	1,312.5	17,262.0	1,011.3	348,267

5.2 Prescribed burning

	Total Mass burned	Emission (Gg)					
Year	Gg	CH_4	N_2O	NO_X	CO	NMVOC	CO_2
1983	4,299	14.2	0.3	10.7	419.3	50.9	7,250
1984	3,681	12.2	0.2	9.2	359.0	43.6	6,208
1985	4,227	14.0	0.3	10.6	412.3	50.0	7,129
1986	4,773	15.8	0.3	11.9	465.5	56.5	8,050
1987	4,949	16.4	0.3	12.4	482.7	58.6	8,348
1988	4,930	16.3	0.3	12.3	480.8	58.4	8,315
1989	2,857	9.4	0.2	7.1	278.7	33.8	4,820
1990	4,148	13.7	0.3	10.4	404.5	49.1	6,995
1991	5,583	18.4	0.3	13.9	544.5	66.1	9,416
1992	3,446	11.4	0.2	8.6	336.1	40.8	5,812
1993	3,466	11.5	0.2	8.7	338.1	41.0	5,846
1994	4,723	15.6	0.3	11.8	460.7	55.9	7,967
1995	4,491	14.8	0.3	11.2	438.0	53.2	7,575
1996	4,497	14.9	0.3	11.2	438.6	53.3	7,586

5.3 Wildfires

	Total Mass burned	Emission (Gg)					
Year	Gg	CH_4	N_2O	NO_X	CO	NMVOC	CO_2
1983	14,492	47.9	0.9	36.2	1,413.5	17.2	24,443
1984	13,633	45.0	0.8	34.0	1,329.7	16.1	22,995
1985	14,418	47.6	0.9	36.0	1,406.2	17.1	24,318
1986	3,368	11.1	0.2	8.4	328.5	4.0	5,681
1987	13,696	45.2	0.8	34.2	1,335.8	16.2	23,101
1988	8,005	26.4	0.5	20.0	780.7	9.5	13,502
1989	5,554	18.3	0.3	13.9	541.7	6.6	9,368
1990	10,756	35.5	0.7	26.9	1,049.1	12.7	18,142
1991	38,049	125.7	2.3	95.0	3,711.1	45.1	64,176
1992	19,682	65.0	1.2	49.1	1,919.7	23.3	33,197
1993	4,578	15.1	0.3	11.4	446.5	5.4	7,721
1994	9,016	29.8	0.6	22.5	879.4	10.7	15,208
1995	6,219	20.5	0.4	15.5	606.6	7.4	10,489
1996	3,552	11.7	0.2	8.9	346.4	4.2	5,991

5.4 Total emissions

	Total Mass burned	Emission (Gg)					
Year	Gg	CH_4	N_2O	NO_X	CO	NMVOC	CO_2
1983	145,124	332.6	15.0	849.9	12,394.3	686.8	244,777
1984	133,338	305.6	13.8	780.7	11,388.3	628.0	224,897
1985	156,404	356.6	16.3	922.2	13,335.2	741.8	263,802
1986	116,192	258.3	12.4	707.1	9,827.2	589.7	195,978
1987	127,356	294.4	13.1	737.6	10,906.8	607.2	214,807
1988	124,132	280.8	13.0	739.1	10,557.7	612.4	209,369
1989	115,620	257.4	12.3	702.4	9,783.1	565.5	195,012
1990	123,114	280.9	12.8	725.0	10,500.0	591.8	207,652
1991	155,398	383.5	14.9	819.4	13,599.3	658.5	262,105
1992	130,740	306.8	13.2	741.8	11,252.1	591.1	220,514
1993	94,287	211.2	10.0	568.3	7,994.5	468.8	159,031
1994	174,684	390.0	18.5	1,057.3	14,795.1	854.8	294,634
1995	181,287	400.6	19.4	1,111.0	15,304.9	896.0	305,771
1996	214,532	468.7	23.2	1,332.6	18,047.1	1,068.7	361,844

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What Technology Can Do

Dr Geoffrey Cary[1]

ABSTRACT

While it is straightforward to document the range of technologies that have been adopted in current fire management practices, identifying the technological developments required for optimal management of fires is a much more difficult undertaking. Information technology, for example, is a fundamental aspect of managing fires and the agencies concerned are quick to adopt new technology as it becomes available. On the other hand, there is limited discussion about the type of information technology required for optimised management of fires. Agencies tend to adopt what is available rather than consider how they might drive research agendas toward more suitable methodologies. Predictive modelling, an important aspect of information technology, is discussed in this light. A spectrum of predictive modelling from simple, experimental fire behaviour models to complex, process-based fire regime models is defined. One end of the spectrum will tell you how fast a particular fire will spread and how difficult it will be to suppress while the other end will tell you what the contribution of that fire is to the overall pattern of fire regime. We all use models from one end of the spectrum on a daily basis while the models from the other end are specialised research tools that require users to be extensively trained. The order of four different examples of predictive modelling along this spectrum is discussed. They are examined in terms of: i) What can the technology do? and ii) How reliably can the technology do it? Two points along the spectrum are of particular importance. The first is the point that represents the most technologically advanced models currently adopted for operational purposes. The second represents that point of technological development required for optimised fire management. The second point is difficult to define but is particularly important, because to some extent, it should help set the fire modelling research agenda in Australia.

1 INTRODUCTION

Technology is the branch of knowledge that deals with science and engineering and its application. It exists in fire management in the form of machines, materials, techniques and processes. For example, fire-fighting hardware represents an area of technology in which there has been considerable development over the last few decades. Technology plays an important role in fire detection, particularly via the remote sensing of fires. There is technology associated with communication, the measurement and prediction of meteorological conditions, the mapping of fires and the production of fire management plans.

Another type of technology that is fundamental in day-to-day fire management is information technology. After all, management is about using information and knowledge to achieve desired outcomes with acceptable costs. This is true irrespective of whether those outcomes are related to the suppression of a fire event or the conservation of biodiversity achieved by optimising patterns of fire regimes. This paper is about the current state of information technology in fire management, what it can do to help with more effective management, and perhaps more importantly, what level of information technology is required for optimising fire management.

The analysis focuses on predictive modelling, a particular branch of information technology that covers some of the most important technological developments in the field of fire management. The purpose of this paper is to promote discussion about the role of predictive modelling of fire behaviour and regimes in modern fire management. Discussion of this nature is required to help clarify the research agenda for fire modelling in the future.

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2 SPECTRUM OF PREDICTIVE MODELLING

There exists a spectrum of predictive modelling ranging from simple, experimental fire behaviour models to complex, process-based models of fire regimes. A fire regime is a description of the nature of the repeated fires that disturb a particular site and has the characteristics of fire frequency, fire intensity and season of fire occurrence (Gill, 1975). The spectrum can serve as a discussion tool for addressing several important questions about predictive modelling including the extent to which fire management agencies have taken up technology as it becomes available and what level of technology is required for effective fire management in an Australian setting.

The simple end of our spectrum is characterised by models that predict how quickly a fire will spread under a given set of conditions. Examples include the McArthur Forest Fire Danger Rating System (McArthur, 1967), the Forest Fire Behaviour Tables for Western Australia (Sneeuwjagt & Peet, 1985), the grassland firespread model of Cheney *et al.* (1998), and the heathland fire spread relationships of Catchepole *et al*. (1999). Typically, these models predict the forward rate of spread of a fire from meteorological, fuel and terrain conditions using empirical relationships derived predominantly from intensive experimentation in the field and observations from unplanned fires.

The complex end of the spectrum is characterised by process-based models that predict the spatial pattern of fire regime using computer simulations. Examples include FIRESCAPE (Cary, 1998; McCarthy and Cary, in press) which was developed for eucalypt forest in Australia and FIRE-BGC (Keane *et al*, 1996) and EMBYR (Gardner *et al*., 1996) which were both developed for coniferous forest systems. FIRESCAPE has been implemented in the Australian Capital Territory Region of Australia while FIRE-BGC and EMBYR were developed for the northern Rocky Mountains and Yellowstone National Park in the USA respectively. These models generate spatial patterns in fire regime by simulating and overlaying individual fire events that are affected by temporal patterns in the weather and spatial patterns in fuel load dynamics and topography.

To better characterise the information technology spectrum, we will consider four different examples of predictive modelling that represent the range in technologies outlined above. These are the Fire Danger Rating System of McArthur (1967), Wildfire Threat Analysis (WTA), SiroFire (a fire event simulator) (Coleman & Sullivan, 1996) and FIRESCAPE (a fire regime simulator) (Cary, 1998). They are intended to provide examples of the different types of technology available, not by any means provide an exhaustive list of all approaches to predictive modelling adopted in contemporary fire management. Nevertheless, they are useful because they can be placed along the spectrum and examined with respect to: i) What can the technology do? and ii) How reliably can the technology do it?

3 WHAT CAN THE TECHNOLOGY DO?

McArthur's (1967) Fire Danger Rating System characterises the simple end of the spectrum in the sense that it makes predictions that are specific for a particular time and place. New predictions must be made for each region of interest or as meteorological conditions change through time. It facilitates the prediction of several aspects of fire behaviour in high eucalypt forest with a standardised fuel load of around 12.5 tonnes.ha $^{-1}$. It can be used to predict the forward rate of spread (FROS), or the rate of spread of that part of the fire burning in the same direction of the wind. The FROS can be corrected for varying fuel load and slope (McArthur, 1967; Cheney, 1968) (Figure 1). It can also be used to produce an index of fire danger, or more correctly, an index based on the variable factors of fire danger (Cheney 1991), including a measure of long-term drought (Keetch & Byram, 1968) and recent rainfall combined into a drought factor; air temperature; relative humidity; and wind speed measured in the open. The fire danger index (FDI), on a scale from 1 to 100, is directly related to the predicted forward rate of spread of a fire and is said to be related to the chances of a fire starting, its rate of spread, intensity and difficulty of suppression (McArthur, 1967). According to McArthur (1967) "an index of one (1) means that fires will not burn, or burn so slowly that control presents little difficulty. An index of one hundred (100) means that fires will burn so fast and hot that control is virtually impossible". FDI values are grouped into fire danger classes (low, moderate, high, very high and extreme) which are a subjective, but expert, classification of the difficulty of suppressing a fire burning in eucalypt litter with the standard fuel load of 12.5 tonnes.ha $^{-1}$ (Cheney, 1991).

The nature of the fire behaviour relationships in McArthur's Fire Danger Rating System were developed from extensive observations from over 800 experimental fires, burning for periods between 15 and 60 minutes, reinforced by observations from a large number of wildfires (McArthur, 1967). The relationships have been expressed as figures and tables (McArthur, 1962), a circular slide rule (McArthur, 1967) and equations (Noble *et al*, 1980). Unfortunately, there was little documentation of the development of the Forest Fire Danger Meter from earlier fire danger rating tables (Cheney, 1991).

Wildfire Threat Analysis (WTA) increases the complexity of prediction in several ways. Firstly it adds a spatial dimension to the predictions that are generally made across a landscape using data from a Geographical Information System (GIS). Predictions do not recognise temporal dynamics in the sense that, similar to fire danger rating, they are again made for a fixed set of meteorological conditions which do not incorporate temporal fluctuations. Secondly, WTA not only incorporates the concepts of fire behaviour (termed hazard in WTA) and the probability of a fire igniting (risk in WTA), it recognises the importance of natural and constructed values that might be threatened by fire. Strictly speaking, a fire danger rating also recognises values at risk (Chandler *et al*., 1983; Cheney, 1991), although as mentioned, McArthur's system is technically a burning index (Cheney, 1968) which does not incorporate values that might be threatened.

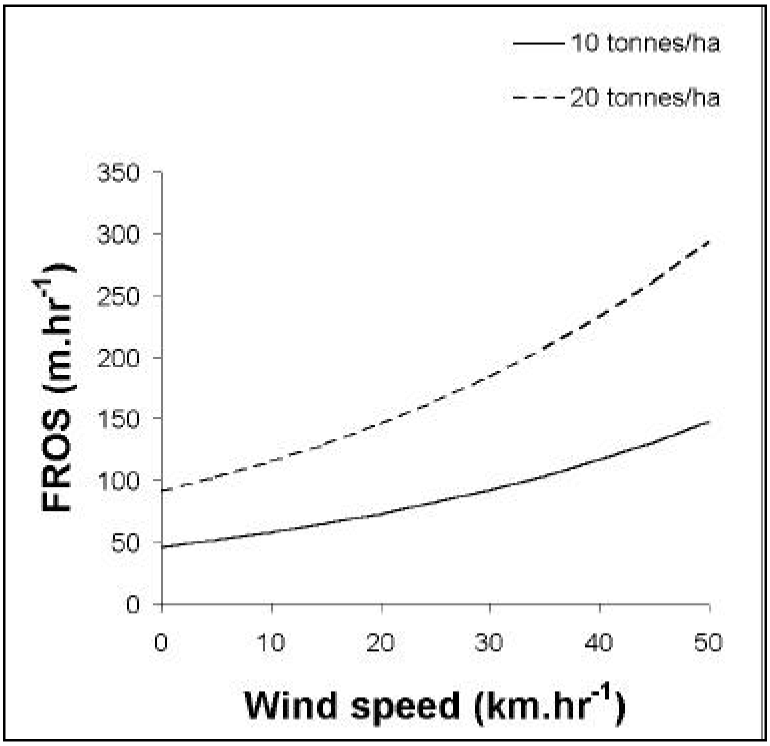

Figure 1: McArthur's Mk 5 Forest Fire Danger Rating System prediction of forward rate of spread for varying wind speed and fuel load on level ground. Other meteorological conditions are: temperature 25 °C; relative humidity 50 %; and drought factor 7.

WTA is an analysis of spatial patterns of hazard, risk of ignition and natural and constructed values, and how they interact to determine wildfire threat across the landscape. The analysis of each component results in a map describing its spatial pattern, although to the author's knowledge, there is no standardised methodology for doing this or for combining the individual components into a map of wildfire threat. The actual form of a WTA produced by an agency is largely up to that agency and might well vary from one user of this form of predictive modelling to another. This is in contrast with current fire danger rating in forests which is determined using one of a small number of systems (e.g. McArthur, 1967; Sneuwjagt & Peet, 1985), depending on geographical location, and which clearly lay out the methods for making the determination. The variability in methods for undertaking WTA needs to be addressed if a national WTA methodology is to be adopted.

Most attempts at WTA remain unpublished in the mainstream literature and therefore are difficult to formally review (although see papers in Bushfire, 1995). The hazard assessment will usually map some aspect of fire behaviour for each pixel in a landscape for a set of user-specified meteorological conditions and for spatially varying fuel load and slope. For example, the fire behaviour relationships of McArthur (1967) may be adopted and applied for a desired set of conditions representing a significant FDI, say the average expected in summer. The predicted rates of spread can be expressed as other measures of fire behaviour including fire-line intensity (Byram, 1959) (Figure 2) or the likelihood of success of fire initial attack (McCarthy and Tolhurst, 1998). Risk assessment may take the form of an empirically derived surface of ignition probabilities or a more subjective classification based on distances from particular land use features such as residential areas and roads. The value assessment should recognise both natural and constructed values. Constructed values are probably relatively easy to determine compared with natural values because they have a replacement value that can be expressed in dollar terms compared with the more abstract value associated with habitat, populations of endangered species, aesthetic appeal and the like.

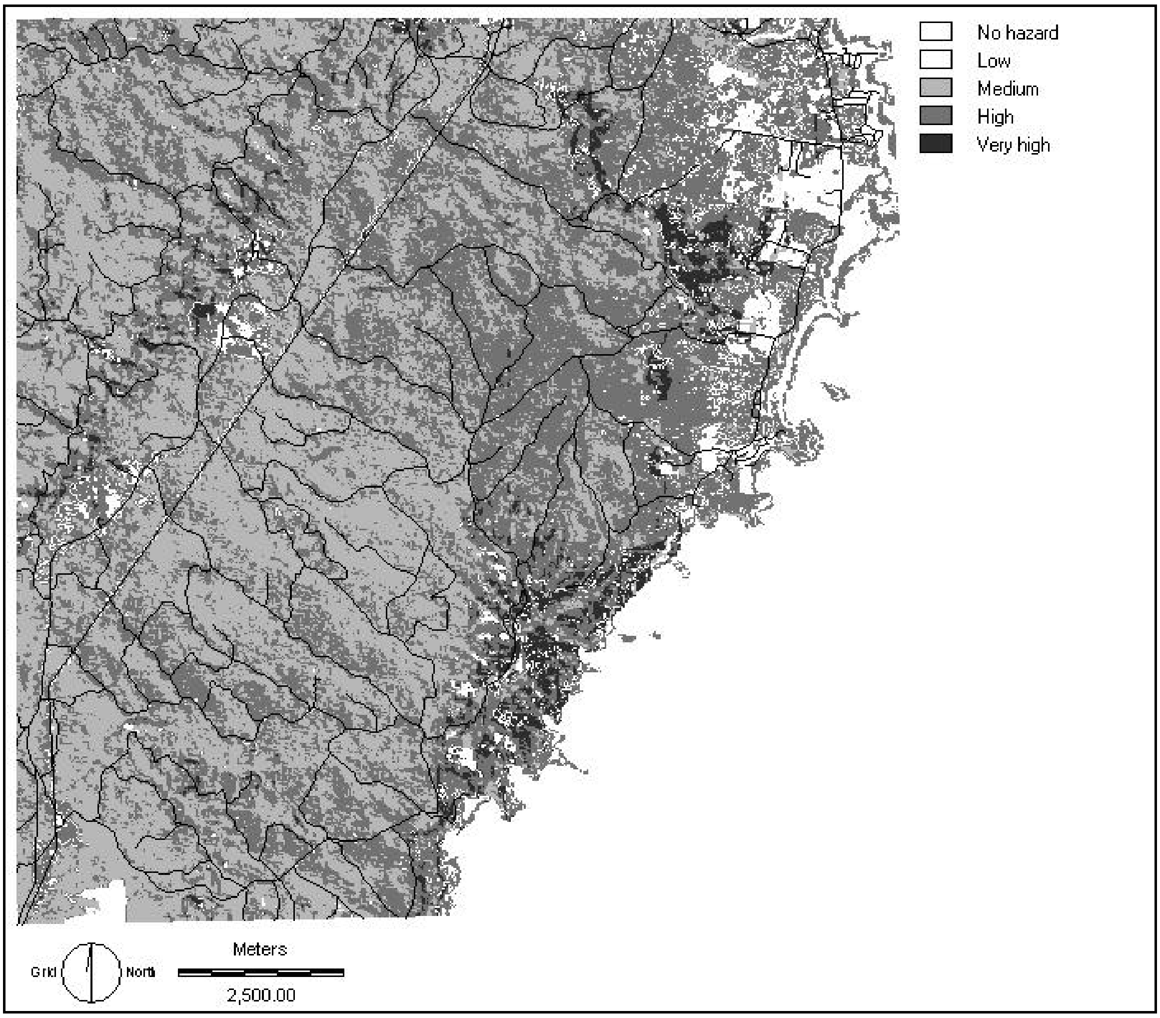

Figure 2: Spatial pattern in hazard for a FDI of 12 for a region of the south coast of NSW. Roads, tracks and a powerlines are also marked. Hazard classes are: Low (1 – 500 kW.m^{-1}); Medium (501 – 2,000 kW.m^{-1}); High (2,001 – 10,000 kW.m^{-1}); Very High (>10,000 kW.m^{-1}). (Source: Amanda Ozolins, Department of Forestry, Australian National University).

Spatial data on hazard, risk and values can be combined in a number of ways in WTA. Wildfire threat can only be high when hazard, ignition risk and values are all high. It is, therefore, a spatial model of fire danger in the true sense (see Cheney, 1991) and is useful for objective discussion of strategies required for the protection of both constructed and natural values.

The next modelling case study adds a temporal dimension and greater complexity in the form of the recognition of fire behaviour at zones other than the head of the fire. SiroFire (Coleman & Sullivan, 1996) is a fire event simulator that predicts the spread of a fire in all directions, not just in the direction of the head fire, and plots the perimeter of the fire at specified time intervals. The shape of the spreading fire is influenced by spatial variation in terrain (derived from a digital elevation model) and fuel type (stored in a geographic database). The user enters fuel load (and fuel curing for grassy fuels) for each fuel type as well as a forecast for weather, which is regional in nature and therefore does not vary across the simulation landscape. The perimeter of the fire is represented by a series of points that are either alight or extinguished.

A fire is spread using the perimeter propagation technique of Knight and Coleman (1993) which is based on Huygen's principle (Anderson *et al.* 1982) and the elliptical fire spread model of van Wagner (1969). In this application, Huygen's principle assumes that every point of the fire front may be considered the source of small secondary elliptical wavelets that are aligned with the wind and which spread out in all directions to form a new fire perimeter at the end of a time step. FROS is predicted from one of five fire spread models and the user specifies which models are to be used for grassland and eucalypt forest fuel types. The models are: i) the McArthur Mk 4 Grassland Fire Danger Meter (McArthur, 1966); ii) the McArthur Mk 5 Grassland Fire Danger Meter; iii) the McArthur Mk 5 Forest Fire Danger Meter described above; iv) the CSIRO grassland fire spread equation (Cheney *et al*., 1998); and v) the Rothermel fire spread equations (Rothermel, 1972). The shape of the propagating ellipses is governed by a length-to-breadth ratio that is related to wind speed. At each time step, a new fire front is defined by the outer points of all the secondary elliptical wavelets (Figure 3). As the fire spreads, the number of points that defines the perimeter is increased or decreased to maintain efficiency and precision.

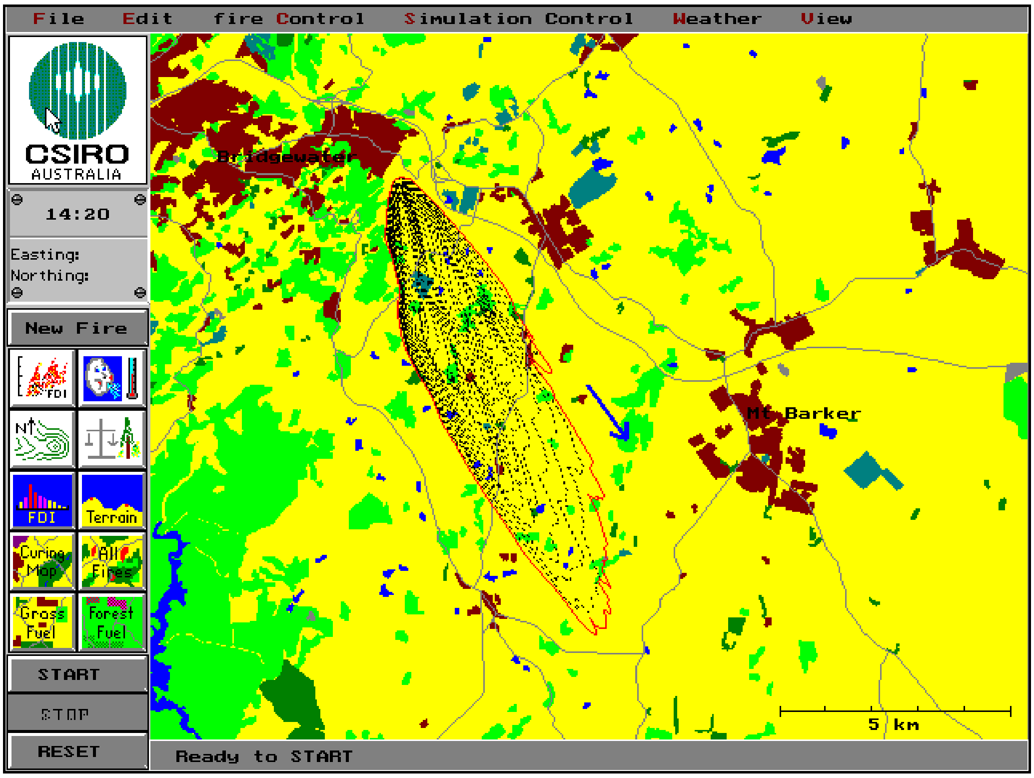

Figure 3: The SiroFire user interface showing a simulated fire event. Ignition was at 11.00 hours from a single ignition point. Current simulation time is displayed on the left of the interface. White areas are grassland, light gray areas are forested, dark gray areas are orchards and black areas are towns. Dotted lines depict old fire perimeters and the arrow at the screen centre depicts the strength and direction of the current wind. Reproduced with permission of the Bushfire Behaviour and Management Group, CSIRO Division of Forests and Forest Products. (Source: http://www.ffp.csiro.au/nfm/fbm/sirofire/sirofire.html).

The final and arguably most complicated example of predictive modelling is that represented by FIRESCAPE (Cary, 1998). FIRESCAPE generates spatial patterns in fire regimes by combining temporal information on weather patterns and spatial patterns in ignition probability with an event simulator that is similar to, albeit less complicated than, SiroFire. Instead of the operator entering the ignition locations (and dates) and meteorological sequences for the simulation of fire events, these are drawn from stochastic models that capture the underlying dynamics of these processes in a particular study area. The discussion of these models is restricted to the ACT region where the most advanced implementation of FIRESCAPE has been undertaken to date.

FIRESCAPE operates on a daily time step when there is no fires burning in the landscape and on an hourly time step when there are one or more fires. Each day of the simulation, irrespective of whether a fire is burning or not, daily meteorological variables are synthesised from a modified form of Richardson’s (1981) weather generator (Cary & Gallant, 1997). The original climate model was modified to include eight variables required for fire danger modelling and to model rainfall using the truncated power normal model (Hutchinson, 1995). This approach generates synthetic sequences of weather based on the stochastic structure of the meteorological process. Various assumptions are made about the patterns of meteorological variables within any particular day and the effect of terrain on meteorology. Daily probability of lightning occurrence is determined from an empirical model which relates thunder occurrence to aspects of temperature and precipitation in eleven years of daily weather data.

Locations of lightning ignitions are modelled by an empirical relationship between lightning strike locations (data from McRae, 1992) and two measures of the terrain. The probability of lightning ignition is positively associated with the macro-scale elevation at the broad spatial scale, primarily reflecting the orographic effect of mountain ranges on storm occurrence. It is also positively associated with the magnitude of the meso-scale elevation residual (the difference between the elevation of a site and the average elevation measured at a broader spatial scale) (McRae, 1992) at finer spatial scales. These relationships are consistent with current understanding of atmospheric electricity and lightning occurrence, and reflect the patterns found in similar studies in Yosemite and Sequoia National Parks, California, USA (Vankat, 1983), but conflict with the findings of McRae (1992).

Once ignited, fires spread from cell-to-cell according to the elliptical fire spread principles (van Wagner, 1969) adopted in SiroFire and outlined above. Forward rate of spread is predicted by the McArthur Mk 5 Forest Fire Danger Meter. It is assumed in the version of the model presented here that there has been no clearing of forest and therefore the meter is suitable for much of the landscape. This is not true in the real world where there are extensive areas of grass-dominated vegetation. Fuel load dynamics are decribed by Olson’s (1963) simple asymptotic litter accumulation curve. Cell-to-cell fire spread is unsuccessful if the predicted intensity of the event is below a threshold that must be determined by the user. Each ignition, if it spreads, results in a single fire event that when combined with other such events define the spatial pattern of the fire regime. At the end of a simulation, spatial patterns in inter-fire interval, fire line intensity, and season of fire occurrence are determined and mapped. Further description of FIRESCAPE can be found in Cary (1997), Cary (1998) and McCarthy and Cary (in press).

The difference between event simulators and fire regime simulators can be demonstrated by examining one output of the FIRESCAPE model, the likely pattern of fire frequency in the landscape (Figure 4). This is clearly the result of thousands of fire events superimposed to specify the fire regime.

There is a general, although not well documented, understanding that for the prediction of FROS, the McArthur Mk 5 Forest Fire Danger Rating System performs reasonably well under mild conditions provided that the user is mindful of issues related to the shape of the head fire and corrections required for fuel load, characteristics and distribution of fuel; slope; spotting potential; time lag in desorption and absorption of moisture by fuel; drying rate of fuel after rain and seasonal drying of fuel; and atmospheric stability (all discussed by Cheney, 1968). On the other hand, the model under predicts rate of spread, by a factor of up to 3, particularly under conditions of high wind speed (Burrows, 1999). The models are only considered as a guide to fire behaviour and the accuracy of predictions of rate of spread should not be expected to be high, particularly at higher levels of fire danger (Cheney, 1991). This is not unreasonable given that the experimental data used to construct the model did not cover the full range of meteorological conditions that the model can predict for, particularly at the higher fire dangers when observations from wild fires were used. Recent research into the behaviour of fires in dry sclerophyll forests will provide data to test existing fire behaviour guides against data collected from summer fires (Cheney *et al*., 1999).

The reliability of the McArthur Fire Danger Meters is fundamental to the other models described because they all rely on it to varying degrees for predictions of the FROS of fires. Many modellers who use McArthur’s meters are aware of their potential shortcomings at higher FDIs but continue to use the algorithms in the absence of an improved relationship (e.g. Cary, 1998).

WTA systems cannot be tested in the way that the other models can because it is difficult to collect data on “wildfire threat”. Nevertheless, several comments can be made from the perspective of the quality of the various sub-models or assessments. For example, the hazard assessment will only be as reliable as the fire behaviour algorithm used in its development. Further, the reliability of the final WTA depends on this and the robustness of the risk and value assessments. If any of the assessments are flawed then so to is the final WTA. This is a critical issue for many different WTA systems because users must often make subjective decisions about processes for which they have little data.

Figure 4: Spatial pattern in average inter-fire interval from a 500 year FIRESCAPE simulation of the ACT region. The ACT border is depicted.How reliable is the technology?

SiroFire can be tested in a more robust fashion and Coleman and Sullivan (1996) compared a SiroFire simulation of the Ash Wednesday fire in the Otway Ranges with a reconstruction of the fire perimeter at various times during the fire run. The model performed moderately well during the initial hours of the fire when meteorological conditions were within the range for which the McArthur Fire Danger

Rating System perform satisfactorily, but less well when conditions were well outside the range for which the McArthur algorithms were designed (Coleman & Sullivan, 1996). The McArthur meter allows calculation of rate of spread in the latter range (McArthur, 1967), but as discussed by Cheney (1991) "all fire danger rating systems have been developed with an incomplete knowledge of fire behaviour over the range of fire danger they profess to cover". The biggest problem in testing SiroFire is the requirement for accurate fire perimeter maps of real fires for comparative purposes. Obtaining relevant meteorological data to run the model can also be problematic.

To date, there has been no robust test of the reliability of fire regime simulation models, again because of the lack of data to accurately test them. Cary and Banks (1999) compared the fire frequency, determined from dendrochronological studies conducted by Banks (1982) in the ACT region, to simulated fire frequency from FIRESCAPE. They concluded that except for one out of five stands, the simulated average inter-fire interval was the same rank order as the observed data, but that the overall frequency of fire in the observed data set was higher. This is not unexpected given that the observed data will include the effect of anthropogenic ignitions while the simulated data does not. However, the test was not particularly conclusive because of the similarity of fire regimes, for pre-European periods, across the dendrochronological sites to begin with.

In a more general sense, McCarthy and Cary (in press) found that there was a reasonable agreement between simulated aspects of minimum inter-fire intervals, average inter-fire interval and season of fire occurrence to those generally recorded for dry sclerophyll forest. On the other hand, the model performed poorly with respect to simulating the relative fire frequency of fire in the mountains versus that in the plains in the ACT as described by Pryor (1939). This demonstrates a deficiency in the model. Possible explanations include the poor representation or absence of important processes in the model and the effect of anthropogenic burning in the real system.

4 WHAT USE IS MADE OF THE TECHNOLOGY?

Compared with the broad applicability demonstrated during the description of predictive modelling above, its adoption in fire management has been somewhat limited. The major exception is the fire danger index (not the fire spread predictions) of McArthur. These have been widely adopted for general fire weather forecasting over the last three decades or so. They were used in the 1960s, as they are today, by the Commonwealth Bureau of Meteorology for fire danger forecasts (Cheney, 1968), which many land management agencies rely upon to set preparedness levels, and for the issuing of public warnings (Cheney & Gould, 1995). Fire management agencies commonly use the fire spread predictions in a simulation setting to demonstrate the importance of particular variables like the effect of wind speed and fuel load on fire behaviour. However, because of the difficulty associated with using the system during large-scale wildfires, they do not routinely make use of the predictions during fire suppression operations. The predictions of spread are more commonly used in planning low intensity prescribed burning operations. Other, more specialised, applications of the system include an examination of temporal trends in fire weather severity in Victoria (Vines, 1969) and prediction on the likely effects of climate change on fire occurrence in Australia (Beer *et al.* 1988; Beer & Williams, 1995).

Adoption of WTA is difficult to accurately determine although it is being used by land management agencies in Victoria, South Australia, New South Wales and Western Australia. Agencies in New South Wales, for example, are responding to the requirement for District Bushfire Management Committees to produce draft bushfire risk management plans (Sections 52 and 54 of the NSW Rural Fires Act of 1997) with wildfire threat analysis of varying forms. Similar legislation exists in other states.

SiroFire is rarely used to simulate fire spread during a fire event, partly because of the need to have the geographic database and digital elevation model implemented before it can be used. Rather, it has been used been used by a number of fire services (NSW Rural Fires Service at Wagga and South Australian Country Fire Service in the Adelaide Hills) to analyse factors affecting fire spread after fire events. It also provides a useful training tool in simulated fire exercises. Bennetton *et al.* (1997) used the model to study the benefit-cost ratio of intervening in 606 wildfires attended on public land in Victoria in the 1991-92 fire season. They calculated that the benefit-cost ratio of the Fire Management Program of the Victorian Department of Natural Resources and Environment in this exercise was around 22 to one.

Process-based modelling of fire regimes has not been adopted in routine operations, however a few agencies, most notably the New South Wales National Parks and Wildlife Service have investigated its potential. For example, Bradstock *et al.* (1998) have developed a simple spatial model that can characterise fire regimes using: i) a knowledge of how the flammability of landscape units changes with time-since-fire and weather; ii) the frequency of different weather classes; iii) the incidence of ignition in different weather classes; iv) the effect of wind direction on fire spread; and v) the upper limit to fire size for any particular type of weather. The model is somewhat abstract relative to the more mechanistic approach of FIRESCAPE, however there are a number of similarities between the structures of the models. The model has been used to investigate the sensitivity of fire-size to the rates of ignition in different weather classes.

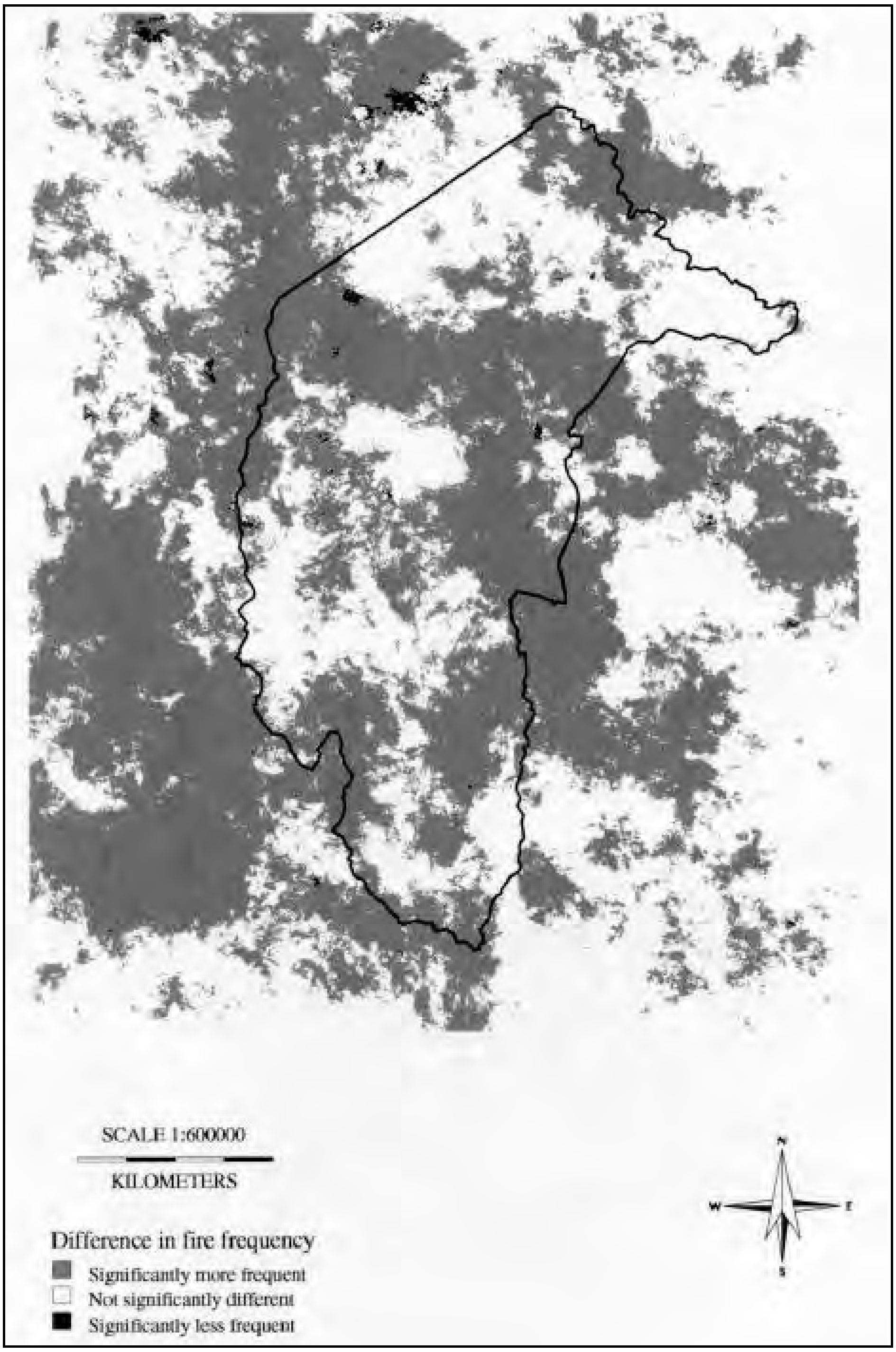

Figure 5: Spatial pattern in cell-by-cell significance of difference between average inter-fire interval simulated for current and changed climates. The climate change scenario increased daily temperature by 2°C and increased summer daily rainfall by 20% (CSIRO, 1992).

FIRESCAPE has been applied in two areas of research. Cary & Banks (1999) and Cary (in press) analysed the sensitivity of fire regimes to climate change resulting from global warming using the FIRESCAPE model (Figure 5). Cary (1997) hypothesised about the size of ignition neighbourhoods of sites and how they might vary for sites in different parts of the landscape (Figure 6). These represent theoretical studies, the results of which may be applicable to fire management but the technology itself has not been adopted to any great extent in modern fire management.

It would appear, therefore, that only the technology at the simple robust end of the spectrum has been adopted in current fire management. The more complex technologies are limited in their application to one or two specialised case studies. Therefore, the point on our spectrum of predictive modelling that represents the most technologically advanced forms of predictive adopted in modern fire management lies somewhere between that represented by WTA and SiroFire.

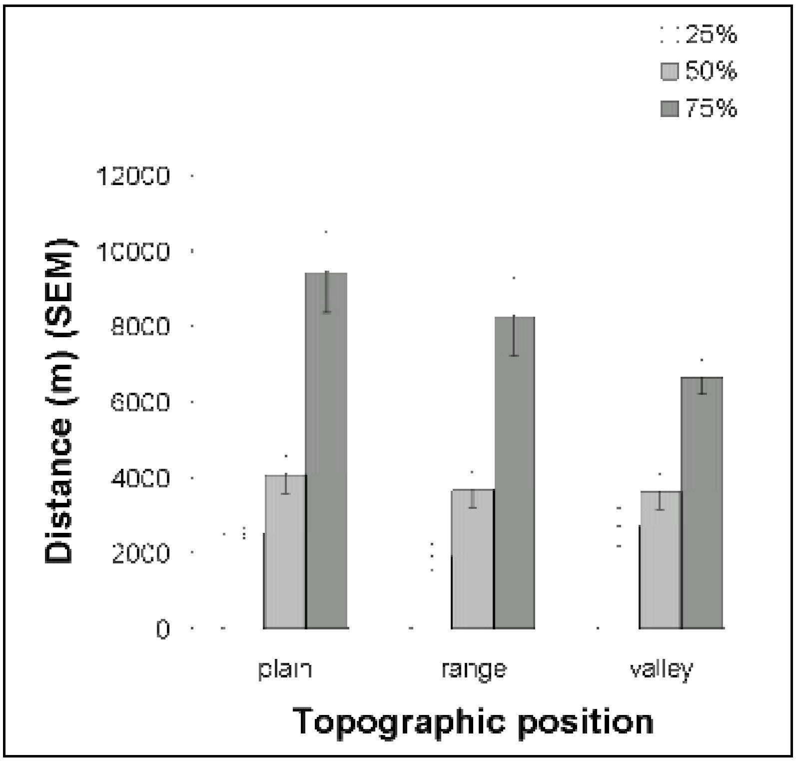

Figure 6: Average distances (metres) to the 25th, 50th and 75th percentile of ignition point distances (for the 3 replicates in 3 varying topographic positions: plain (sites located on relatively large, flat areas); range (sites located on top of major peaks or ranges); and valley (sites located near the bottom of major valleys). Results from a 1000 year FIRESCAPE simulation of the ACT region.

5 WHAT TECHNOLOGY IS REQUIRED FOR OPTIMISED FIRE MANAGEMENT?

Of the four case studies, the more complex technologies (event simulation and fire regime modelling) are the least well adopted. This may be partly due to the complexity of associated with them and partly because of their relatively recent advent. One might assume that they will be adopted as a matter of course, however, it may be prudent to discuss their role in fire management before considerable research funding and time is invested in their further development.

An ability to accurately predict the likely spread of fires in near real time using event simulators must be advantageous to fire agencies. It is curious there has not been more extensive adoption of this type of technology. There are two factors that have probably limited this in the case of SiroFire. Firstly, that the model is not implemented in a windows environment which leaves the perception that the technology is outdated. Secondly, the database format used in SiroFire is not matched to the geographic information systems used by the majority of land management agencies. This problem is compounded by many of the land management agencies in different states choosing to use different GIS systems to each other.

An ability to predict spatial patterns in fire regimes across landscapes is also surely advantageous in fire management. Managers often use surrogates for knowledge on fire regimes such as the presence of a particular species with a well-known response to varying fire frequency, the dynamics of fuel loads and simple rules of thumb about the effect of terrain on fire regimes. This demonstrates a need for the type of information that the fire regime simulators can provide in a quantitative fashion. Nevertheless, the benefits that may be derived from a more comprehensive knowledge on fire regimes must be considered in light of the complexity associate with developing and implementing the technology. If there is general consensus that this, the most complex of the technologies discussed, does have a role in day-to-day fire management, then further research and development is required. On the other hand, if fire managers consider that the technology is too complicated for their needs, then the fire regime simulation will remain in the realm of theoretical research and applied research must focus on improving the reliability of the other forms of predictive modelling. The decision ultimately lies with fire management agencies that must fund the research, at least in part, as is the case with recent research into the behaviour of summer fires in dry sclerophyll forest.

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Debates About Aviation

Mr Lloyd Johns[1]

This paper was presented as part of the "Managing Fire" panel session and has undergone slight editorial changes by Professor P Schwerdtfeger, Chairman of the Organising Committee.

My first operational experience with aircraft as fire suppressant vehicles was the day following "Ash Wednesday" 1983. I was Director of Country Fire Services here in South Australia, and the State was on its knees, having experienced the most severe wild fires in many, many years - 8 fires had, the day before, consumed 2000 square kilometres of rural and urban interface land and property, from Clare in the North to Kalangadoo in the South. Four fire fighters and 22 civilians had perished and the burns unit at Royal Adelaide Hospital was overflowing; 500 houses had been destroyed in 11 hours of sheer devastation…

The worst had passed - fire fighters were back in control - but there was still a lot of work to be done extinguishing hundreds of outbreaks in and around the Adelaide hills and in directions North, South, East and West. Around 10.00am one of my senior officers said to me - "Boss, a couple of months ago we managed to get the Board to agree to trialing aircraft for fire fighting - why don't we put it to the test and get some planes in the air to hit some of the hundreds of fires we still have to extinguish" my reply was - "Do it!!"

What followed was a mixture of desperation and pioneering - in the next 48 hours we blew the entire initial annual budget for aerial fire fighting for the SA Country Fire Service, dumping many tonnes of unthickened di-ammonium phosphate throughout the fire ravaged areas - to this day there is no clear indication that the operation was either a success or a sheer waste of money and it was not until I sat down to write this paper that I realised just how important that small part of what, at the time, was a battle for survival, was to be in shaping my future views and commitment on the suitability of aircraft for fire suppression activities in Australia.

This paper very briefly looks at events which have shaped the way in which Australia uses aircraft for the dropping of retardant or foam; the use of aircraft for fire control, fire spotting, troop transport etc is not addressed.

Apart from the Victorian Forest Commission, very little use of aircraft for the dropping of fire retardant or water appears to have occurred in the years 1939 - 1965.

It was during the early eighties that Victorian Forest Commission trialed the MAFFS (Modular Airborne Fire Fighting System) which fitted into the Hercules C130 military aircraft and dropped long term retardant chemicals ahead of forest fires. There is not a lot of recorded information on the success or other wise of the system, but suffice to say the modular unit was returned to the USA and nothing more evolved.

It is not surprising that in the years 1935-85 foresters drove wildfire research and the practical trialing of fire suppression methods and techniques - as brave as the volunteer bush fire fighter was, and still is, rural fire fighting organisations were woefully under-funded and under-staffed; forestry, on the other hand was a commercial operation, and it was in the best financial interests for forestry operators to invest in the protection of valuable assets.

It is my considered view that a combination of factors shaped Australian wildfire research and in particular how aircraft are used for fire suppression. Not the least of these was the United States influence - foresters appeared to have had very close ties with their US counterparts and regularly visited the USA on study trips and exchanged information with each other. When I took up the post of Director and CEO of SA Country Fire Services, it was not long before the foresters on our Board, and those we worked with, made it clear to me that the US Federal and State Forestry Authorities were "respected colleagues".

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So when it came to aerial fire fighting, there was only one path to follow - the US model.

Aerial fire fighting in the USA is a multi-million dollar a year business and has been for many years - I'm sure you've all seen the movies glorifying the US fire fighting aviator. For many years the basic procedure had been that you acquired ex-military or commercial aircraft at bargain basement rates, spent around a $US100,000 to convert them to a fire fighting aircraft and then loaded them up with fire retardant chemicals and flew them until you either collected your pension or didn't come home from your mission!

Is has changed considerably in recent years - the requirement for airtankers to have turbine powered engines has forced the conversion costs of C130/P-3 type aircraft to as high as $US1.3 million and even higher for non-turbine aircraft. Even so, the USA is still heavily committed to the use of large tankers and long term retardants and as opposed to early and direct attack using Class A foams, this must result in the sacrifice of valuable forest assets.

In 1982 - the year prior to Ash Wednesday the CFS Board and I enthusiastically supported "Project Aquarius" - the Federal Government funded investigation into the use of large aircraft for fire fighting in Australia. The project was organised and undertaken by the CSIRO Division of Forest Research. The South Australian Country Fire Service contributed with the provision of a research officer and to the funding of research into fire fighters' protective clothing and heat stress - one of several sub-projects carried out in conjunction with the main project. A number of the sub-projects produced valuable and practical results - the main project, dogged by an exceptionally wet fire season, and in my view, poor project management, was a disaster.

Having moved from trials in Western Australia where the wettest summer season in 27 years had deluged much of the work being undertaken, the party moved to Gippsland, where an almost equally wet summer season sabotaged the project. The project had engaged the services of an ageing DC6B tanker aircraft owned by "Conair" - an aviation fire response company operating in the province of Vancouver. It transpired that the only day suitable for lighting fires and dropping retardant was designated a fire ban day in the Gippsland area and no fires could be lit - was this possibility ever thought of in the planning of this costly project?

If the planners and organisers of the project had conceded that the primary objective of the costly trials could not be achieved, most, if not all interested parties would have accepted that statement and looked at alternatives, but instead of admitting that there were no definitive conclusions as to the suitability of large aircraft for fire fighting a document titled "Aerial Suppression of Fires - A Cost Benefit Analysis for Victoria" was produced and has since become known as the 'Project Aquarius Report'.

This document has been used to manipulate official stances on the use aircraft for fire fighting in Australia and in particular to denigrate the capabilities of the Canadair Amphibious fire fighting aircraft which has become universally known as the "SuperScooper".

One can only despair at the impact this presentation - produced at a project cost of around (1982) $3.2 million without generating observational data- has had on the decisions surrounding the use of fire fighting aircraft in Australia in the seventeen years since. In a speech to the Australian Federal Senate, Senator John Coulter discredited the "Project Aquarius" document by reporting no less than 314 estimates, rough estimates, broad estimates, overestimates, assumptions, extreme assumptions and preferred assumptions made in the report. The faults and inaccuracies revealed by Senator Coulter's findings were so appalling as to warrant grave caution against the document being viewed as a credible contribution to both local and national decision making in the future protection of Australia from the ravages of wild fire; and yet the document was hailed - and still continues to be quoted as <u>the</u> definitive study on the use of large aircraft for fire bombing!

In the time that has followed, the Canadair aircraft continue to be dismissed as a serious consideration for use in Australia, in spite of their having been enthusiastically adopted by almost every Mediterranean country in Europe. I have in my possession a plethora of statements in the form of letters of reply, magazine articles and radio and TV records of interview - from Premiers, Ministers, Parliamentary Secretaries, fire officials and small aircraft operators which range from the bizarre to the mischievously inaccurate and all point to one conclusion - in Australia the Canadair aircraft has never been seriously considered on its merits and there is no immediate indication that this will change. The opportunity for evaluation which was extended during a placement of two Canadair aircraft by the company in Adelaide during the summer of 1997-98 resulted in their being ignored in South Australia, but saving the day after a long eleventh hour dash to a serious fire in the Dandenongs near Melbourne.

There is no question that a whole range of aircraft can be effectively utilised for fire control - Canadair owns the name "Integrated Fire Management System" which is used to describe the operation of both a range of aircraft and ground management systems for wildfire fire control. This system was developed by Canadair and Canadian and foreign government foresters as a sensible, cost-effective wildfire control system.

The Australasian Fire Authorities Council has issued a "Position Paper" on the use of aircraft for firefighting. In the paper they state, among other things:

> "large capacity purpose-built fire fighting aircraft are expensive to acquire, operate and maintain and require investment in infrastructure and support services.
>
> Such investment would elevate fire suppression costs to unprecedented levels. This level of investment has not been justified by experience, research, economic studies or information obtained from fire suppression agencies overseas. While the concept of importing airtankers which are idle during the northern hemisphere winter is superficially attractive, research, including the recent AFAC aircraft evaluations (of the CL415 and the Russian IL 76TD) has demonstrated that the investment required to import, operate and support these aircraft cannot be justified at present."

On its own, this statement sounds pretty reasonable, but one must ask the question – "What experience, what research and what economic studies support the statements?" For example, the document quotes the Loan and Gould economic report - is this one of the factors which have decided the present and future protection of Australian lives and property from wildfire? Further more, the aircraft has a multi-task capability and it has been long argued that the use of the aircraft for coastal protection, immigration control and disaster relief could make the aircraft an extremely valuable tool for the protection of Australia in general and its environment in particular.

While Australia has focussed on telling the public why the aircraft should not be here, other countries have evaluated and re-evaluated their options - Canadair aircraft numbers have grown steadily from a total of 54 in 1981 to a total of 139 in 1999 - if they were unsuitable, not cost effective or they "scoop up too many scuba divers", then why have original customers upgraded their fleets and new customers leased or purchased aircraft, not the least of which is the war-torn Republic of Croatia which now owns 2 x CL215 and 2 x CL415 and has a third turbo-prop 415 on order!!

Until there is a radical change in attitude on the part of both fire suppression officials and others, the innuendo and misinformation will continue and the citizens of Australia will be denied the protection they so rightly deserve.

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Debates over strategies for fire-management

Dr Ross Bradstock[1]

ABSTRACT

Debates concerning aspects of bushfire management are diverse, complex and usually most vigorous in the aftermath of significant or disastrous (in human terms) fires. Debate about fire management strategies often reflects the fact that areas of fire-prone vegetation are subject to multiple objectives of management. Such objectives are often poorly understood or articulated. Another source of debate involves perceptions about the causation of fire "disasters". The impetus to attribute blame for a disastrous fire is strong. Many disastrous fires, however, involve a chain of incidents and a conjunction of circumstances that a belie a simple, single cause. Similarly, much debate over strategies revolves around the utility of unilateral solutions (e.g. suppression technology, prescribed burning, house design, town planning etc.). Arguments about management especially in the wake of disastrous fires are often coloured by the perpetuation of myths and hyperbole through popular media. The injection of politics adds another dimension to such arguments. Given the complexity of circumstances surrounding major fires and management imperatives for fire-prone areas, its likely that strategies for fire management will be multi-faceted. Ultimately, for debate to be productive, it must focus on an informed choice between differing strategies. Studies that capture the complexity of the problem and which examine the sensitivity of outcomes (i.e. the size and intensity of unplanned fires coincident with severe weather; the set of fire regimes that may occur in landscape) to differing strategies are required. The management of fire-prone bushland within the Sydney region of NSW is used as a case-study to illustrate these general points.

INTRODUCTION

The term strategy implies manipulation. Similarly the term debate implies argument over options, choices or at least, points of view. Why are alternative strategies debated? Why do alternatives exist in the first place? Landscape fires (bushfires in Australian parlance) are complex phenomena - an emergent property of the interaction of physical (weather, terrain etc.) and biotic (vegetation, people etc.) factors at relatively large spatial and temporal scales. In part the answer lies in this complexity, or more specifically, our limited understanding of it. Fires also affect a wide range of things that are valued by humans. Differing people place differing emphases on these effects, and thus fires, are perceived by people in a multitude of ways. These elements provide a rich cocktail for debate.

In this paper debates about fire management are considered in the context of fire as a general land management factor. The fire problem as it relates to land management, is simply, the definition of an appropriate set of fire regimes that suit the defined land management objectives for the area. In tandem with this is the human dimension to the problem, namely the provision of a secure and defensible environment for humans and their property, when situated in close proximity to bushland. These two facets of the problem are not independent. That is, the choice of an appropriate set of fire regimes for a landscape may influence decisions about the ideal solution for the human environment. Note that the overall physical, climatic and biotic context of any landscape will influence the solution. Thus differing solutions may be needed for different places.

How well does contemporary debate serve to provide a solution to the problem? In general, debate about fire management has a dual purpose. It must lead to a consensus about appropriate fire regimes and the nature of a secure human environment. It must also reach a conclusion about the best way to

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implement such a consensus. It is arguable that much debate is inadequate in this regard and thus fails to advance a solution to the fire management problem in general.

Debate is obviously shaped by the major themes of fire management. In turn a range of human (e.g. management and social) issues intersect with these themes to influence the clarity, quality and overall outcome of debate. The aim of this paper is to outline these themes and issues, to review some typical examples of debate and to speculate about how general debate may evolve in the future. The intention is to highlight unproductive conflict and to promote discussion and concepts that will lead to improvement in our ability to understand and co-exist with fires. Awareness of the underlying issues and appropriate knowledge of relevant phenomena are highlighted as key requirements for the conduct of satisfactory debate.

1 THE NATURE OF DEBATE

More education and surveillance?
More protection of people?
More aeroplanes?
More "natural" fires?
More prescribed burning?
More concrete?
More evacuations?

Table 1: Some typical questions concerning fire management strategies.

Debate about fire management strategies is diverse and complex (Table 1). The list of questions provided in Table 1 are by no means exhaustive but is merely indicative of commonly asked questions. Of course the converse of any of these questions may be posed with equal vigor. Some may also be unfamiliar with the wording of the questions that are posed. Note that each of these themes can be related to either or both of the two facets of the general fire problem stated above: i.e. some deal with the nature of fire regimes in the landscape while others are oriented at the human environment.

These themes of debate over fire management relate to five basic processes or functions.

1. Prevention of unplanned fires (education, surveillance, enforcement etc.).
2. Manipulation of fuel (prescribed burning, mowing / slashing, grazing etc.).
3. Suppression technology (dozers, tankers, chemicals etc.).
4. Urban design (building design, materials, town planning etc.).
5. Management of people and their safety (status and roles of residents, emergency services, problem of voyeurs etc.).

Some themes of debate take place within these categories. For example the use of large aircraft with water bombing capability is proposed by some as a more cost-effective solution than the use of small aircraft. Other debates range across these categories. For example some may contend that a technological solution to fire suppression may supplant any need for appropriate building design and town-planning (i.e. technology has the potential to suppress all unplanned fires). Others may argue conversely that extensive prescribed burning may supplant the need for a large suppression force. In principle "intra-categorical" debates of the former kind are less complex. Thus they should be easier to resolve than "inter-categorical" debates which must traverse a plethora of options and perspectives.

A range of human issues that influence the scope, quality and ultimate utility of debate are:

- value judgements and their overall influence on objectives of land management;
- the clarity of land management objectives;
- the responsibility and accountability of individuals, communities and governments;
- the level of resources available to devote to the problem;
- the role of the media;
- the political and legal context.

1.1 Are Debates Productive?

Debate is arguably most productive when there is at least consciousness, and some degree of consensus, about these issues amongst parties. Debate is also more likely to be productive when land management objectives and responsibilities for action are clearly articulated and levels of resources are understood among parties. There are both positives and negatives concerning the use of the media and the legal system as fora for debate. It is vital that debate is open and wide ranging. The complexity of the issues underlying fire management pose an ongoing challenge to media and legal instruments. It is difficult to tease out the issues and explain the nature of complex physical and biological phenomena (often partially understood) to interested people who are not professionals in the field. The adversarial nature of courts is daunting for the "expert" witness who may at best be only to attribute a probability to a key event or process.

The timing of debate has a large bearing on its quality and utility. Debate about fire management strategies is ongoing but is publicly prominent and usually most vigorous in the immediate aftermath of bushfire disasters involving the destruction of property and human casualties. In the inter-regnum between such events, debates are usually the province of special interest groups and those with a professional interest in the field. After a disastrous fire, debate becomes more widespread and public. The reasons are obvious: the media briefly take interest in and promote issues and opinions; legal inquires provide a another formal outlet for opinion; people who are adversely affected suddenly become aware of problems they may not have recognised before.

Debates in the aftermath of disastrous fires have a particular flavour. People, understandably, seek reasons for what has happened. Often such answers are elusive for a variety of reasons. Analysis of disastrous fires takes time and debate is often conducted before such analyses have been completed, or in some cases even commenced. Many disastrous fires involve a complex chain of circumstances, such as the coincidence of severe weather with an ignition source, a particular configuration of fuel in the landscape, chance events such as spotting at crucial times, the presence/absence of people at critical times and places etc. The difference between a human disaster or a near miss may hinge on small variations in many of these factors. A single cause may be difficult to unequivocally pin down. Instead such disasters may be more adequately understood as the conjunction of a multitude of factors, which all play some pivotal role in the chain of events. In itself, this conclusion indicates that strategies for bushfire management need to be multi-faceted. There is no unilateral solution that is universal.

The problem of complexity of causation is compounded by the nature and use of the media at the time of disasters. Fires are spectacular events, which when they occur in close proximity to humans, provide much dramatic material for reporting. The drama surrounding fires often leads to exaggeration in the description of phenomena and events. Common examples include the overestimation of basic fire properties such as flame lengths and rates of spread by an order of magnitude or more, in some cases. Such distortions are understandable given the inexperience of observers and their physical and emotional state at the time. Nonetheless inaccuracy and hyperbole create a climate which may not be in the best interests of rational inquiry and debate. The media are also used as a means of attributing blame and identifying scapegoats. The urge to apportion responsibility for a disaster is often strong for obvious reasons. People have a genuine desire to rectify the situation so that a repetition may be averted. However disingenuous scapegoating that is overtly or covertly intended to undermine the credibility of people or institutions is unfortunately common at the time of fire disasters. Often the intent is not to identify causes and responsibilities but rather to serve some wider agenda. Serious misrepresentation of the position and policies of public agencies and individuals can often occur and it is incumbent upon the media to ensure that the basis of opinions are adequately scrutinised.

Whether or not the aftermath of disastrous fires is the best time to debate such issues is a moot point. Ultimately debate about causes, accountabilities, strategies and future action is not well served by a climate of innuendo and hyperbole. The focus on the "event" often draws attention from the fundamental issue of the fire regime (see above). That is, the consequences of the event can only be fully understood in the context of what has happened in the past. Alternative strategies that may have changed the course of the event need to take this into account.

Irrespective of when it takes place, much of the debate over fire management strategies often has overtones of fundamentalism: i.e. it deals only with extremes or absolutes. Often the options are much wider than is first apparent. Polarity of opinion often flourishes among people with widely differing values, and when such values are poorly articulated as land management objectives. Fundamentalism thrives on a lack of detailed analysis of the problem and in the absence of knowledge of key processes and phenomena. Aspects of this problem are dealt with in detail in the example below.

Processes are needed which ultimately bring debate down to solutions on the ground and which allow the expression of a diversity of ideas and viewpoints in a fair and rational way. Arguably, an appropriate co-operative planning process provides such process and an outlet for parties to channel their viewpoints and ideas in a constructive way.

1.2 A Case Study

Debate about the fire management strategies is ongoing and vigorous in the densely populated parts of southern Australia. The Sydney region provides an interesting case study because of the close proximity of a burgeoning urban and rural population with bushland that is fire-prone. In turn such bushland is rich in terms of biodiversity and is highly valued in its own right by people, for a variety of purposes. Major fires resulting in losses to people and their property are episodic. It is arguable that the interval between such events is often sufficient in many localities to cause complacency. Debate therefore shows many of the characteristics discussed above. Much of it takes place only after major fire events. Argument often centres on the roles of prescribed burning and techniques for suppression. Here the role of prescribed burning in fire management strategies is chiefly addressed.

The problems of conflicting values, perceptions and fundamentalism are exhibited prominently in public debate about prescribed burning in the greater Sydney region. Opposing factions exist which differ in terms of underlying beliefs or values. On the one hand there are those that see any form of burning (planned or unplanned) in bushland as unnatural. On there are those who regard the bush as “adapted to fire” and thus extensive burning as beneficial or benign. As a result debate is sometimes conducted on the basis of a dichotomous choice of strategies only (extensive prescribed fire versus no prescribed fire). The reality is however that there are many possible options. Surprisingly, there is little information about the nature of these choices and the way that such options can be implemented and matched to objectives for land management. The underlying ecological reality is that of fire regimes: i.e. plants and animals cope with some regimes of fire but not others. In simple terms this means that there are times when it appropriate to burn and other times when it isn’t. That is, the circumstances of past fire events condition the responses of plants and animals to a potential fire at any given time.

Prescribed burning can serve many practical purposes and is one of the most incisive and powerful instruments of fire management. In terms of the general fire management problem stated above, it can contribute to the determination of a desired set of fire regimes and it can provide a contribution toward safe and defensible human space. Typically after major unplanned fires affect humans and their property in the region, there is a call for more burning. While this is an understandable response, the utility of debate is often clouded by the problems described above. A call for more burning as a solution to destructive fires implies an analysis of the effectiveness of existing programs of prescribed burning and considered judegments about the likely impact of increased activity. Unfortunately debate has often occurred without the benefit of such analysis.

A study (Bradstock *et al.* 1998a) was conducted in an attempt to shed light on the putative relationship between level (area) of prescribed burning and human protection in the region. This study was oriented solely at the problem of safe and defensible human space. Prescribed burning can be used as a tool to manage fuel levels at the urban interface (the junction between houses and the bush). In this manner fuel is reduced in order to lower the intensity of any subsequent fire in severe weather. A reduction in fire intensity at the bushland interface in close proximity to houses (circa 100 m) serves a dual purpose. A reduction in leaf litter (surface fuels) and shrub foliage (elevated fuel) may also reduce the propagation of embers during fires in severe weather. Embers are a key agent implicated in the ignition of buildings (Ramsey *et al.* 1996). A restriction of fire intensity also allows suppression of fire and protection of property to be carried out by fire-fighters in a safe and effective manner.

The study by Bradstock *et al.*(1998a) examined prescribed burning levels in relation to an index of protection (Fig. 1) for the much of the urban/bushland interface across northern Sydney (about 200 km in length). The study involved modelling to integrate the effects of terrain, differing fuels (vegetation types) and variations in weather (based on retrospective analyses of daily weather) with relevant fire behaviour models. The results (Fig. 1) indicate that a high proportion of the interface is required to be burnt each year in order to reduce the number of days with potential for uncontrollable fire intensity to minimal levels (maximum protection). Note that the index of protection was highly sensitive to changes in level of burning. Current levels of burning at the interface are relatively low, thus ostensibly, there is scope for more burning at the interface to substantially increase protection. Indeed, more burning at the interface could achieve higher levels of protection.

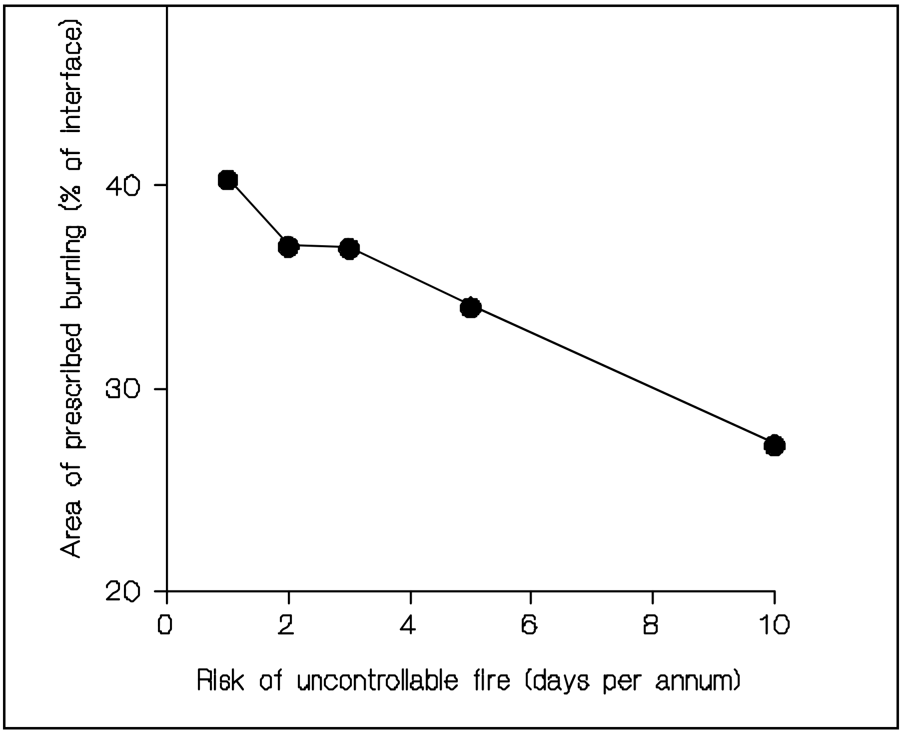

Figure 1: The relationship between amount of prescribed burning and resultant risk of occurrence of conditions suitable for uncontrollable fire at the urban interface in northern Sydney.

In the context of the creation of a safe and defensible human environment, debate about the amount of burning at the bushland interface is a non-event: more will be better. The problem with such debate is not the amount of burning but the reality of implementation. The community as a whole faces many problems and choices in implementing a strategy of burning at the urban interface.

i) The boundary of bushland does not neatly correspond with boundaries of tenure. It is difficult to define who is responsible for action when the boundary is intertwined with private, local and state government lands. Individual actions or inaction directly affects neighbours. Decisions about manipulation of fuel at the interface for protection are therefore not simply a matter of individual choice without regard for others.
ii) The community as a whole does not have unlimited resources to tackle the problem. High levels of protection require high levels of burning (Fig. 1), in turn requiring a significant increase in resources. Is the community willing to fund an appropriate increase in resources?
iii) The level of burning required to achieve high levels of protection may be constrained by factors such as weather and related issues such as air quality. Appropriate weather for prescribed burning in autumn and spring is relatively limited. Use of volunteer labour (restricted to weekends in the main) may further curtail the choice of days available. Mild, stable weather, ideal for prescribed burning, may result in a build-up of smoke in the greater metropolitan area. Burning may therefore be vetoed by authorities concerned with regulating air pollution in order to safeguard human health.
iv) Burning to achieve high levels of protection in an ongoing manner will result in a fire regime that will be adverse to native plants and animals. High frequency burning has been shown to eliminate prominent components of the flora and habitat for animals in these ecosystems.

When viewed in this way any debate about "more burning" at the urban interface may be regarded as superficial. In essence the debate is not so much about burning as about the level of protection we are willing to accept given the above constraints to the problem. What level of resources and opportunities are available and how can we best optimise these to achieve protection? Given the inherent compromises and constraints, what level of protection is realistic? Such questions need to be brought to the attention of the community in general. There is also a requirement for further study of the problems that underpin these questions and to provide a reasonable appraisal of options.

2 WIDER CONSEQUENCES - ALTERNATIVE STRATEGIES, PLANNING AND ZONING

The biodiversity problem raises wider issues about the context of the landscape and other management objectives. In large landscapes in this region a diminution of biodiversity may be tolerated if it is confined to a relatively small area such as at the urban interface or other points in the landscape that may serve some strategic purpose. Localized losses may be accepted in order to satisfy multiple objectives of management (human protection and biodiversity conservation) in bushland areas adjacent to urban development. This implies that fire regimes may be manipulated in a different manner away from the interface or areas of strategic importance, with the emphasis there weighted toward objectives concerning conservation or other facets of land-use, other than human protection.

Such compromises cannot be achieved in small areas. A relatively small strip of bushland can constitute a serious problem to adjacent buildings should a fire occur in severe weather, particularly if fuel loads are high. A case in point is the destructive fire that occurred in 1994 in the southern suburb of Jannalli (over 100 structures destroyed). The destructive fire developed rapidly from a point ignition in a bushland area less than five hundred metres wide. The question posed for such areas is should management be strongly weighted to securing a safe and defensible environment for humans or should it be directed toward other objectives. Such choices are difficult in isolated bushland remnants where there is little history of any recent destructive fires. Note that the choices involve value judgements about management objectives that may be difficult to resolve.

The above example illustrates the consequences of one approach to the prescribed burning problem in the Sydney region. Intensive treatment of the urban interface is one approach or strategy but other options exist. Some may argue that protection can be achieved through active use of fire for manipulation of fuel in parts of the landscape that are remote from the urban interface. Much burning of this kind occurs. Is such a strategy a surrogate or is it complementary to intensive treatment of the interface? If burning is carried out remote from the interface will it reduce the chance of a major fire reaching the interface? Where, when and how much burning should such a strategy involve? How do we contend with multiple objectives of management? There is little in the way of objective analysis that can provide insight into such questions. Recent developments in modelling of the spread of fires in landscapes (see Cary this volume) provide one means of scrutinizing these questions. For example Bradstock *et al.* (1998b) examined random and patterned strategies of prescribed burning using simple spatial models representative of the region. They found that a high proportion of the landscape would need to be burnt annually to significantly reduce the size of unplanned fires coincident with severe weather. Models of these kind predict that high levels of prescribed burning, have no effect on the incidence of unplanned fires in extreme weather.

The level of prescribed fire needed to "passively control" (restrict the spread) of wildfires, would result in a fire regime that would lead to a high probability of extinction of the rich shrub component of the local flora (Bradstock *et al.* 1998b). Thus extensive or "broad area" prescribed burning is unlikely to satisfy multiple land management objectives (human protection and biodiversity conservation) in these landscapes. The challenge, in terms of debate over prescribed burning, is to find an appropriate strategy (area and configuration) that satisfies these multiple management objectives. Preliminary results from landscape modelling suggest that the most appropriate strategy is to employ prescribed burning as an "active" means of control of unplanned fires: i.e. prescribed fire is used to facilitate effective fire suppression (Williams and Bradstock 1999). In general terms this means that prescribed burning should be targeted at places in the landscape where suppression is likely to be accessible and effective. Further modelling work and empirical studies are required to investigate this idea and to objectively compare the performance of differing strategies.

3 CONCLUDING REMARKS

Insight and information are important pre-requisites for an informed debate. Ultimately arguments about strategies also require practical resolution. Informed decisions need to flow from debate and a process that can channel and resolve arguments is required to achieve this. Recent developments in threat analysis and bushfire planning provide such a practical basis, particularly in situations where land tenure is varied and complex. In NSW for example, the Rural Fires Act of 1997, has provided the stimulus for Risk Management planning at the broad landscape scale (Douglas 1999). Concurrently, planning initiatives by land management agencies such as the National Parks and Wildlife Service provide a complementary approach for specialist land tenures (Conroy *et al.* 1997). Planning of this kind can successfully bring together people with disparate interests and viewpoints.

A notable feature of contemporary planning is the use of zoning as a way of resolving the problem of multiple objectives. A zoning approach strives to delineate differing land uses and differing priorities for management at a relevant landscape scale. As a consequence the differing sets of fire regimes required for various management objectives can be openly discussed, defined and focused on the ground. Perhaps most crucially, such planning provides an opportunity for community-level discussion of how best to employ the limited resources that are available for fire management and to apportion responsibility for action among individuals and government agencies.

Planning as a forum for debate over strategies is a relatively low key activity that does not figure strongly in the public consciousness, despite considerable effort to engage disparate parties and to promote the finished product. In no small measure this is because such planning is ongoing during times when bushfires do not figure strongly in the public mind. Debate over fire management strategies will continue, but we can anticipate an era where a more clear understanding and definition of land use objectives will lead to more productive debate. We can also anticipate an era where much more is known about the way in which the various arms of fire management shape the nature of fire regimes in landscapes. We have little quantitative knowledge of this kind at present, but developments in landscape modelling of fire regimes (Cary this volume) offer much promise.

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Recent Advancements in Weather Observation and Forecast Technologies relating to Wildfires in Australia

Mr Andrew Watson[1]

ABSTRACT

The Bureau of Meteorology in Australia maintains a key national role in the provision of both observational and forecast information to fire agencies and the community in general. Technological advancement has greatly enhanced the capacity to detect and analyse meteorological data, much of which is now available in real time and at high resolution. Data from ground level upward through the entire troposphere is retrieved from a wide variety of sensors either on the ground, airborne or in space. Over the past decade the Bureau has developed several new weather observing and diagnostic systems. In addition to this, large quantities of meteorological data from other sources are now accessible.

Ground based technologies include Automatic Weather Stations which have proliferated across Australia over the past decade. In South Australia alone, the Bureau has a network of almost 50 stations which provide real time temperature, humidity, rainfall, wind and atmospheric air pressure data. Some of these units are remotely located, such as on south Neptune Island, and at Ernabella in the far north west of the state. Weather data from these stations is communicated to the meteorologist via satellite, radio or land line, and is crucial in tracking systems such as cold fronts and mid latitude cyclones which can dramatically affect the behaviour of wildfires.

Vertical atmospheric profilers which use small variations in the refractive index of the atmosphere to sense the temporal changes in both horizontal and vertical winds are becoming more commonplace. Profilers can provide tropospheric and stratospheric wind data on a continuous basis, which is a considerable step forward from the six hourly observations obtained from the Bureau's weather balloon radiosonde network. The conventional network nonetheless remains an important component in the observational database.

Weather radars provide information on the location and intensity of precipitation within a radius of 250 kilometres. Most of the populated regions of Australia now have weather radar coverage. Computer terminals provide the software platforms which enable the meteorologist to undertake detailed analysis of precipitating weather systems, allowing diagnosis of the recent and probable future evolution of rainfall areas which may directly affect wildfires.

Lightning detection systems have developed over the past few years to the point where they now provide accurate real time information on the location and time of cloud to ground lightning strokes. Well recognised as a wildfire ignition source, lightning activity can now be closely monitored, providing fire combating agencies with additional intelligence, both on a predictive and a post analysis basis.

A variety of space based satellites are instrumented to provide a range of data relevant to the detection of wildfire related phenomena. Examples of the types of available data are:

- a derived vegetation “index” which provides information on vegetation greenness and therefore its combustibility;
- “hot spots” at ground level indicative of burning wildfires;
- wildfire smoke plumes and their extent, density and propagation;
- the type, height, extent and evolution of tropospheric cloud;
- the strength and direction of winds in the middle and upper layers of the troposphere.

New and improved remote sensing technologies will continue to come on line, with Bureau innovations including the aerosonde, which is a small, remotely controlled aircraft capable of flying missions of up to 72 hours to specifically targeted weather systems such as cold fronts and tropical cyclones.

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Refinements in the output resolution of numerical weather prediction models continue, with an Australian operational model with 5 kilometre grid resolution planned for implementation in the year 2000. This will assist forecasters in the prediction of small scale weather features which can influence wildfire activity. This should flow on to more useful forecast information for fire agencies.

1 SURFACE OBSERVATIONS

1.1 Automatic Weather Stations

The Automatic Weather Station (AWS) used by the Bureau of Meteorology is a ground based sensing instrument which, under the implementation plan of the past decade has proliferated across Australia. In South Australia, the Bureau currently has a network of almost 50 stations, illustrated in Figure 1.

Many of these AWS are located in remote parts of the state, such as on south Neptune Island, and at Ernabella in the far north west of the state. A denser network of stations has been installed in the vicinity of Adelaide (within the dotted square in Figure 1) to ensure the detection of smaller scale weather systems which may impact on the major population and economic centre of the state.

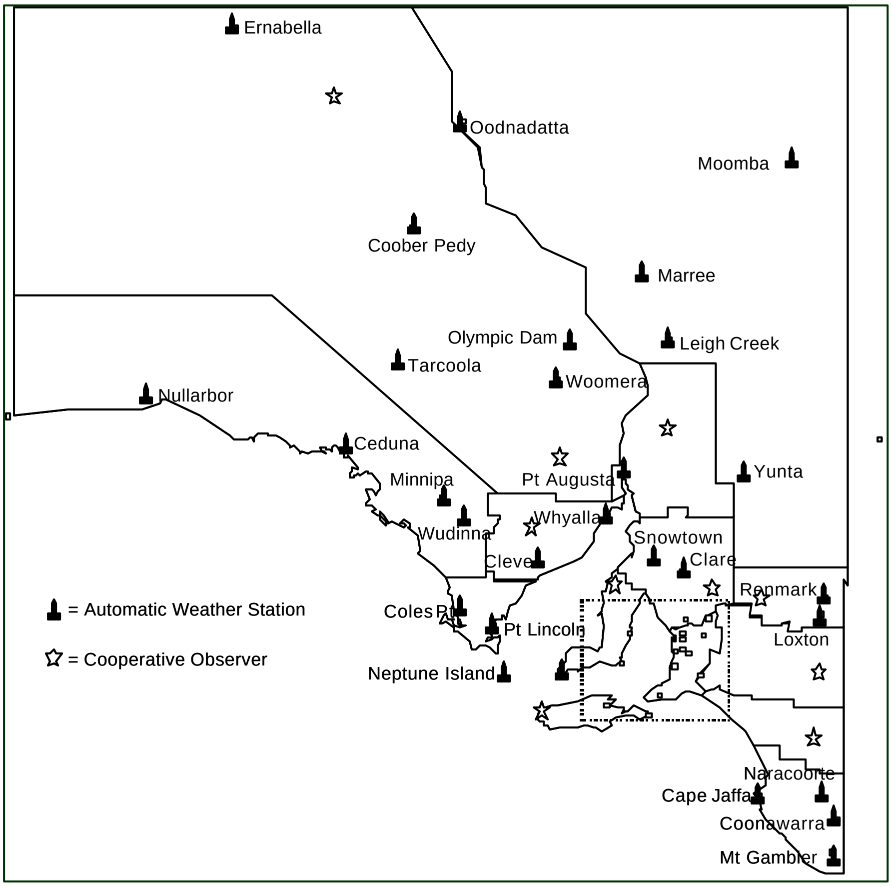

Figure 1: AWS network in South Australia.

Each unit provides the forecaster with temperature, humidity, rainfall, wind and air pressure data in real time. Automatic weather stations are gradually phasing out the human “co-operative” observer who has been paid by the Bureau to take manual weather observations a transmit these to the forecast centre.

Data from the automated stations is communicated via a range of channels, including satellite, radio, or land line. The data can be displayed in many formats, allowing the meteorologist to quickly assess the weather situation and make well informed decisions. One effective means of displaying the data is in a graphical time series format, with an example shown in Figure 2. These data were recorded by the AWS at Mt Crawford in the Mount Lofty Ranges, about 50 kilometres to the northeast of Adelaide. This representation shows clearly the fluctuation of wind speed and direction over approximately 24 hours. The change in wind direction associated with the passage of a cold front can be seen, as can the coincidental increase in wind speed. A wind gust to 50 knots (93 kilometres per hour) coincident with the passage of the front is clearly depicted.

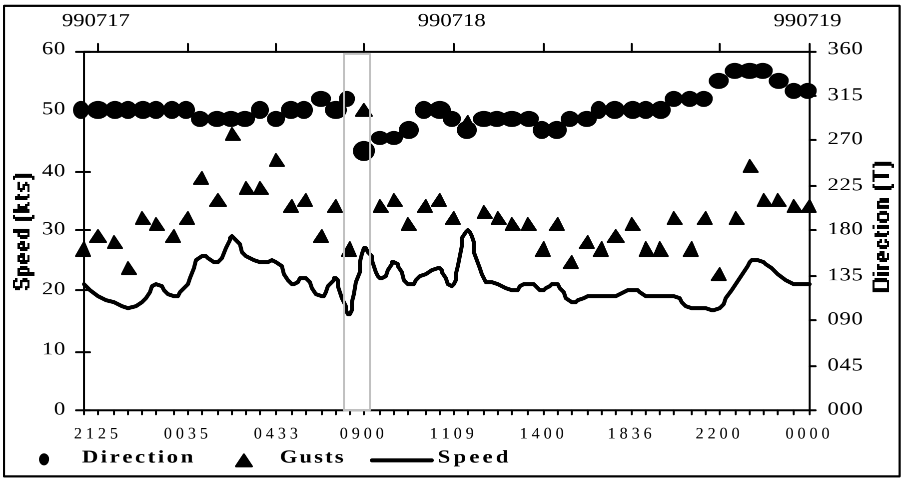

Figure 2: Time series (left to right) showing wind data from Mt Crawford AWS in the Mt Lofty Ranges. The hatched area shows the passage of a cold front.

These types of data are crucial to the task of accurately monitoring weather systems such as cold fronts and mid-latitude cyclones which can dramatically affect the behaviour of wildfires.

2 RAINFALL OBSERVATIONS

2.1 Weather Radar

Weather radars installed and operated by the Bureau provide detailed temporal and spatial information on the location and intensity of precipitation out to about 250 kilometres radius from the radar. Most of the populated regions of Australia now have weather radar coverage.

Computer workstations running appropriate software analyse and display the data from the radars. An example of output from the Sellicks Hill radar south of Adelaide can be seen in Figure 3. This radar observes rainfall over the greater Adelaide area and beyond. The screen display allows the meteorologist to quickly assess the structure and evolution of precipitating weather systems. This diagnosis provides the basis upon which short term rainfall forecasts are made and can serve as very pertinent information to wildfires activity.

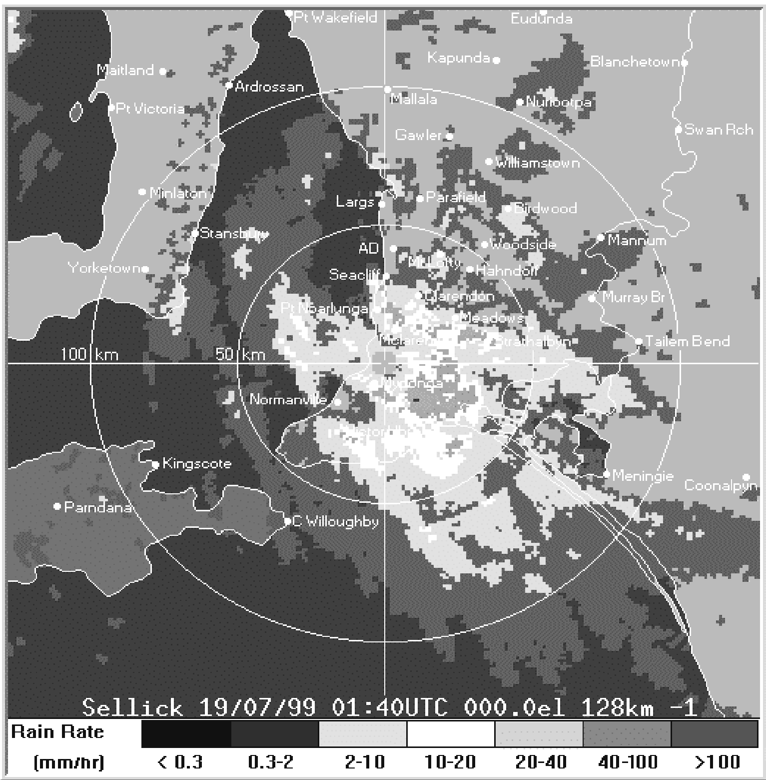

Figure 3: Weather radar image from Sellicks Hill radar. Areas of moderate to heavy rain are depicted on 19 July 1999.

Signatures in the weather radar data can also provide an indication of the likelihood of lightning and thunder. This can be vital information to the planning of resource deployment by fire combatant agencies. It is also critical information to the issue of advices and warnings of severe weather systems which might produce flash flooding, damaging winds or large hail.

3 UPPER ATMOSPHERIC WIND OBSERVATIONS

3.1 Vertical Profiler

Traditionally, the Bureau has observed the weather elements of upper levels of the troposphere through the release of weather balloons from a network of stations across the country. When tracked by radar, radiosondes and reflecting targets attached to these balloons provide wind, temperature and humidity data from the upper layers.

A steadily evolving substitute to this conventional technology is the atmospheric profiler. This is a ground based array of antennae which transmit a radar beam vertically. Small variations in the refractive index of the atmosphere caused by turbulence are detected in the backscatter to the profiler. Computer algorithms then deduce the speed and direction of both horizontal and vertical winds, which can be displayed in various formats on terminal screens. The example from the Mount Gambier profiler (Figure 4) shows how the forecaster can view a time series of horizontal winds every half and hour at vertical intervals of 250 metres. This is a considerable step forward from the conventional 6 hourly observations available from the balloon network.

4 LIGHTNING OBSERVATIONS

4.1 Lightning Detection Network

Lightning is well recognised as a common wildfire ignition source in Australia. Over the past few years lightning detection systems have been developed to the point where they now provide accurate real time information relating to the location and time of lightning strokes.

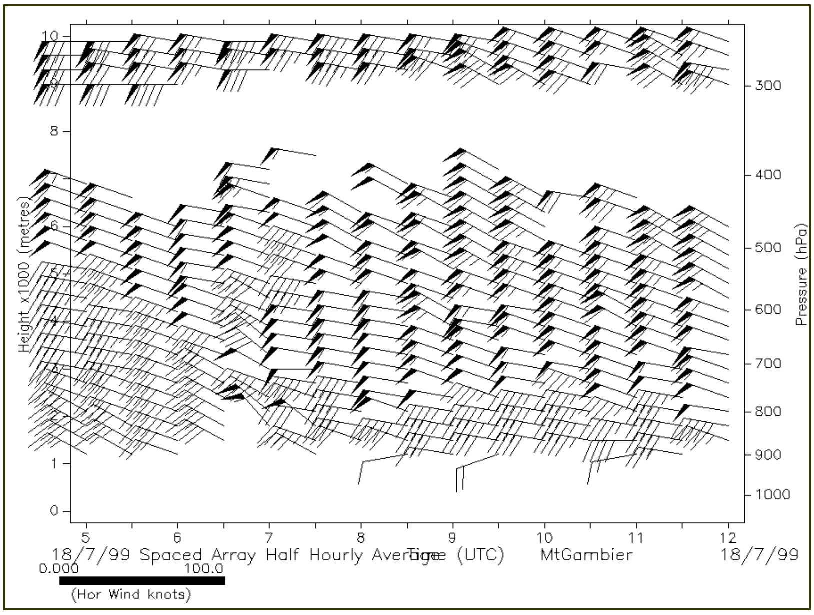

Figure 4: Data display of upper winds from the Mt Gambier profiler. Winds direction is from left to right. A short barb represents 5 knots of speed, a long barb 10 knots and a flag 50 knots.

The Bureau currently pays for access to lightning data from the detection network of a privately owned organisation. This network provides coverage of all of eastern and central Australia. Within a few years the network will extend across the entire country.

Ground based sensors detect the radio wave emissions produced by lightning bolts. If at least three sensors in the network detect the time of arrival of a single lightning stroke, then the position of the stroke can be determined, as well as the time.

Geographical information computer software then displays the data on a map, providing the forecaster with real time information on the location and frequency of lightning. Since lightning is coincident with thunder, this information is also very useful in monitoring the location and intensity of thunderstorms. Figure 5 shows an example of how the system displays lightning activity.

This lightning detection system is now extensively used to by the Bureau and fire agencies, providing intelligence on the possible locations of wildfire ignitions, which can be valuable in both a fire predictive sense, and in the post analysis phase.

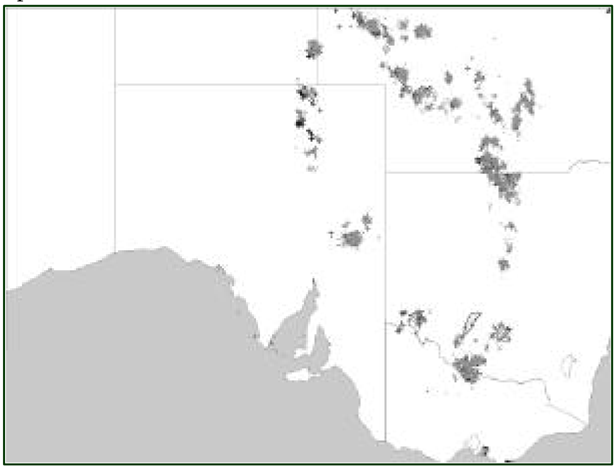

Figure 5: Lightning strikes, south eastern Australia, 19 March 1999. More than 7000 strikes were recorded within 1 hour on this day.

5 SATELLITE OBSERVATIONS

5.1 Fuel State

There is a wide variety of space based satellites which are instrumented to record and transmit a range of data relevant wildfires and related phenomena.

For example, the greenness (moisture content) of vegetation can nowadays be derived from satellite radiometers which can detect the difference between the black body radiation emitted by green plants from that radiated by brown, or dead plants. The moisture content of a plant is directly related to its combustibility, so this data is particularly valuable to fire agency people, who, as the fire season progresses, can closely monitor the changes in fuel state of grassland or forests over wide areas. It is a major step forward from the traditional labour intensive process of assessing fuel moisture content. This involved obtaining samples of fuel from grasslands and forests, and physically measuring the quantity of moisture retained by the plants. Whilst being an accurate technique, the area which can be assessed is very limited, with considerable interpolation required. The remote sensing capacity of the satellites provides a much more comprehensive and efficient system for fuel state assessment. An example of the variation in fuel state across South Australia in late spring of 1998 is shown in Figure 6.

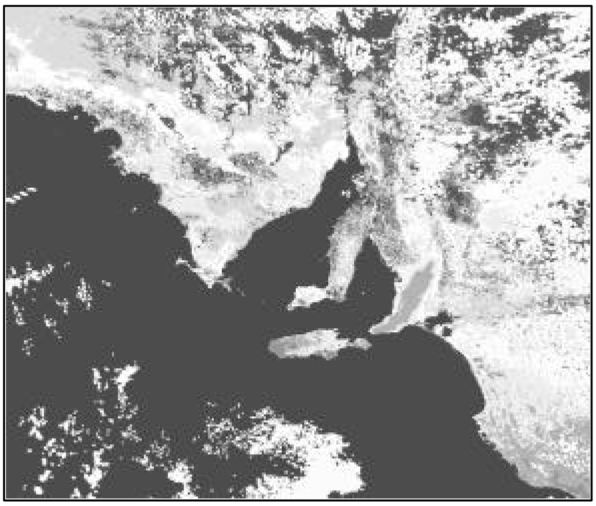

Figure 6: Satellite sensed differences in vegetation greenness, late November 1998.

5.2 Smoke Plumes

Weather satellites are used extensively to observe weather patterns around the globe. Many weather systems are accompanied by clouds formed by the condensation of water vapour.

Clouds not associated with water vapour are also detected by weather satellites. These include ash clouds from volcanic eruptions, and smoke plumes resulting from wildfires. Intense fires can create plumes which extend thousands of metres vertically into the troposphere. When the smoke extends into zones of strong tropospheric winds, it can be advected hundreds of kilometres in the direction of the wind. The extensive spread of smoke plumes caused by several major wildfires in New South Wales in January 1994 are clearly evident in Figure 7.

In this case the smoke from the fires can be seen extending large distances from the fire sources. Much of the smoke and ash was carried over the Tasman Sea by the strong upper level northwesterly winds, with some ash falling in Auckland, New Zealand.

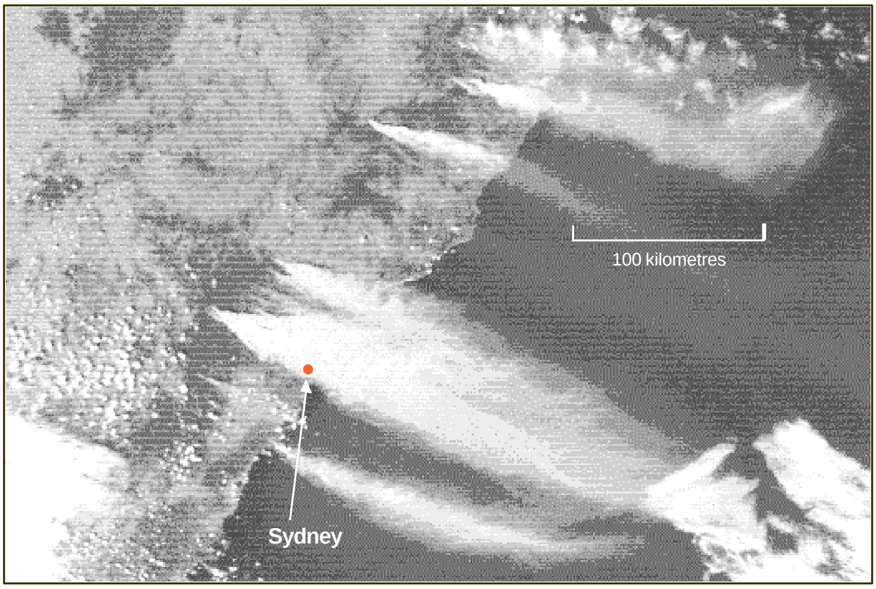

Figure 7: Wildfire smoke plumes, New South Wales, January 1994 as detected by satellite.

5.3 Hot Spots

Because of the heat generated, the location of large wildfires can be detected from space by the infra-red sensors on satellites. This “hot spot” information is useful to the fire combatant agencies in assessing accurately the location of the fires, and which flank of the fire is burning most intensely.

5.4 Clouds

Satellites are used extensively world wide by weather forecasters for the detection and analysis of clouds consisting of water droplets. Infra-red and visible imaging techniques provide the tools for the identification of the type, thickness and height of these clouds. Cloudiness has a direct effect on both the likelihood of fire ignition, and also on the intensity at which going fires burn. Rain falling from clouds clearly has a major mitigating impact on fire behaviour. Consequently an accurate assessment of the amount of cloud, and its evolution into the future is crucial to the operations of fire agencies.

Some satellites now have the capability to accurately monitor the movement of clouds and through the application of appropriate algorithms deduce the wind speed and direction at various levels of the troposphere.

In addition to the data retrieved from balloon releases and atmospheric profilers this is becoming a valuable source of upper atmospheric information. Figure 8 shows an example of how satellite retrieved upper wind data can be displayed over an infra-red cloud image of southern Australia and the adjacent ocean areas. This is a convenient way of relating the upper winds to the cloud formations, and can serve to verify (or otherwise) the assumptions made by meteorologists. Information from previously data sparse regions such as the oceans is especially valuable, and will serve to enhance the understanding of atmospheric processes on the broad scale.

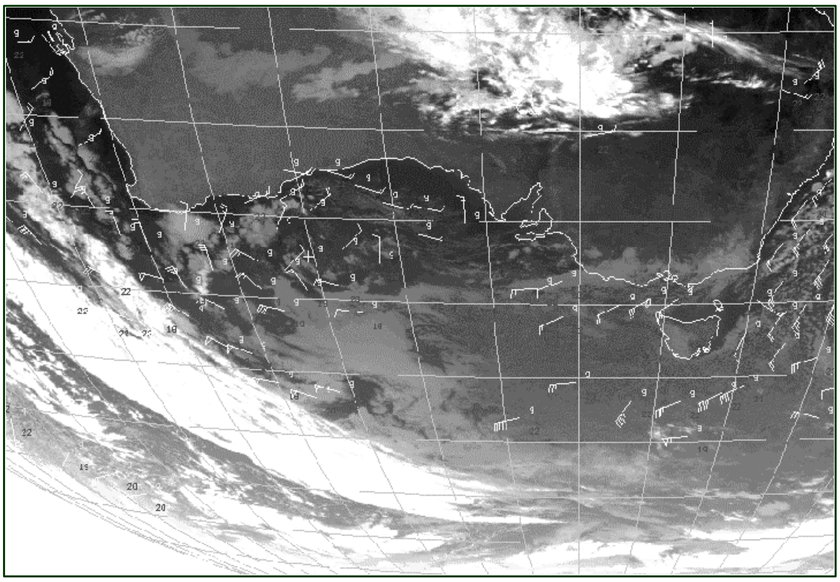

Figure 8: Infra-red satellite image showing cloud features. Overlain wind barbs show satellite detected wind speed and direction at 5000 feet elevation.

6 COMPUTER MODEL WEATHER FORECASTS

With the rapid increase in computing power over the past decade, improvements in the quality of computer weather prediction have been dramatic. Weather services in many countries, including Australia, now have computer models which produce weather analyses and forecasts for the entire globe. Over 4 million weather observations can be processed by these supercomputers at any one time. By applying the observation data to the physical and dynamic equations of the atmosphere, a prediction of the future state of the atmosphere out to more than a week can now be made. These predictions form the basis of the seven day weather forecasts which are routinely available to the public in Australia. This information is clearly of great value to the planning activities of the fire authorities.

Nested within the global models are finer scale prediction models which are used over smaller domains. Figure 9 shows output from the Australian "meso scale" model, depicting the predicted near surface wind flow over South Australia. Vectors show the expected wind speed and direction at a spatial resolution of 25 kilometres. Contours provide further detail on the variation of wind speed. The position of a cold front is indicated.

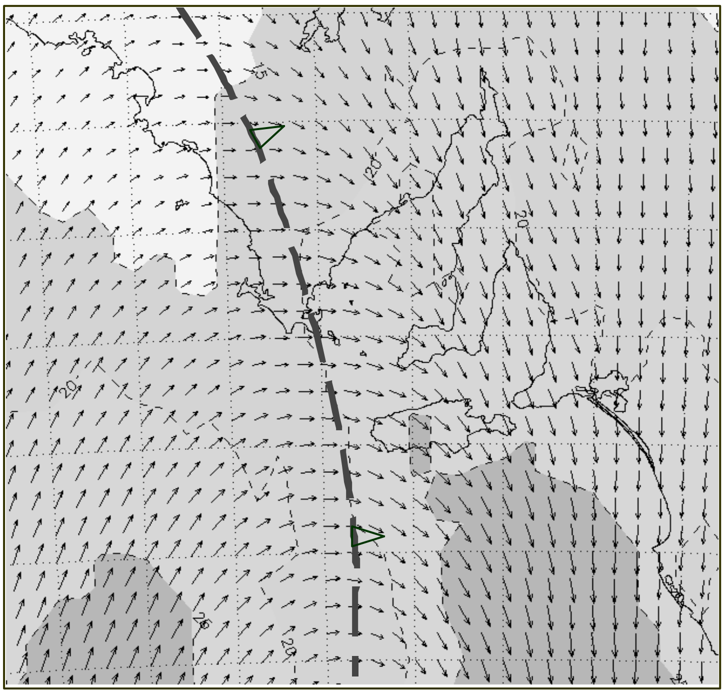

Figure 9: Near surface wind predictions by the Australian "meso scale" weather prediction model.

Refinements in the output resolution of these "meso scale" models continue, with an Australian model with

5 kilometre grid resolution planned for implementation in the year 2000. This will further assist forecasters in the prediction of small scale weather features which can dramatically influence wildfire activity. This should flow on as very useful forecast information for fire agencies in the both the short term prediction of fire potential, and also in determining the direction and rate of spread of burning wildfires.

7 SUMMARY

Recent advances in technology have lead to a greatly enhanced capacity to retrieve, display and analyse meteorological data, much of which is now available to the forecaster in real time and at high resolution. From ground level upward through the atmosphere, data is retrieved from a wide variety of sensors, some of which have been illustrated in this paper. Over the past decade many new weather observing and diagnostic systems have been developed, and the Australian Bureau of Meteorology has developed several. A large volume of meteorological data is available from other sources world wide.

Automatic Weather Stations provide real time temperature, humidity, rainfall, wind and atmospheric air pressure data at ground level. Vertical atmospheric profilers sense the small scale changes in both horizontal and vertical winds through the troposphere. Weather radars provide information on the location and intensity of precipitation within a 250 kilometre radius. Lightning detection systems provide accurate real time information on the time and location and of lightning strokes and their accompanying thunderstorms. Orbiting satellites are instrumented to provide a range of data relevant to the detection of wildfire related phenomena, such as the dryness of the grassland and forests, smoke plumes and hot spots associated with burning wildfires, the type, height and extent of clouds, and the strength and direction of winds in the upper layers of the troposphere.

Improvements in numerical weather prediction models continue, with a very fine scale Australian model planned for implementation during the year 2000. This type of tool will assist forecasters in the prediction of small scale weather features which can have a major impact on wildfire activity. It is anticipated that these developments will flow on to progressively more useful forecast information being available to fire agencies. Hopefully this will assist in further reducing the impact of wildfires on the Australian community in fire seasons to come.

The Art of Fire - The Significance of Fire in the traditional Aboriginal Performing Arts of Arnhem Land[i]

Professor Margaret Clunies Ross*

Fire is a subject of fundamental importance to all human societies, including those of past and present Australia. It is important for its practical uses as well as its natural properties, which are powerful and may be dangerous. Fire is usually of use to humanity to the extent that its effects and properties can be controlled. For most human societies, if not all of them, the nature and origin of fire has been a subject of mystery, about which explanations have been sought, and, in many cases, the explanations offered for the nature and origin of fire have taken the form of myths. It was not obvious to the pre-scientific world where fire came from, how things that were not burning one minute could burst into flame the next. Nor was fire always available when and where people wanted it; sometimes it was present when people did not want it and could not control its ravages, as in volcanic eruptions or bushfires. At other times, people needed it to cook with, to make tools with, to warm themselves with and to create light in darkness, and it was not available or it had gone out. Fire was unpredictable as well as mysterious and it has always been difficult for humans to control.

It is not surprising, then, that many human mythological systems have represented fire as having come from outside their world, as having been brought from the divine to the human sphere, often in questionable circumstances. One thinks of the classical myth of Prometheus, son of a Titan, who stole fire from Mount Olympus, and taught humans, whom he had made from clay, how to use it. For this he was horribly punished by Zeus: he was chained to a rock in the Caucasus, and every day his liver was eaten by a vulture, to be restored again at night. Promethean fire was something divine that humans were not intended to have had; there was something transgressive in its acquisition and that transgressiveness perhaps expresses the tension between the force and natural properties of fire and the desire of humans to tame it, to domesticate it, as it were, and thereby create the lineaments of human culture, defined essentially as the ability to cook food, make tools, establish comfortable settlements and organised social groupings and mark the transitional points of a human life, from birth through adulthood to death.

We may perceive something of the same transgressive quality as the Prometheus myth displays in many traditional Aboriginal Australian myths. One such comes from South Australia, and was recorded by Berndt and Berndt in the early 1940s (1993, 235-6 and 450-1). It associates the origin of fire with the killing of a Whale spirit being at a dance at a ceremonial ground in the Hindmarsh Valley. Whale is tricked into dancing by other spirit beings because they perceive that fire emanates from his body; it is something they want and do not have and something they are willing to kill for:

> At last Whale danced and as he did so sparks issued from his body. At that time the people had no fire and when they saw it they were excited. They talked about how they could obtain some. Skylark said he would spear Whale. Wagtail agreed and said he would spear Whale while Shark, Stingray and Seal were dancing. They called out to Whale, 'Come and dance so that we can applaud you!' Whale danced while Wagtail fitted his spear into a spearthrower. However, Skylark told Wagtail, 'I'll spear him'. Whale came dancing close to where Skylark stood. He speared him so that the spear sunk [*sic*] deep into the back of his neck. Fire gushed out. Skylark grabbed some of it and ran away, setting alight to the surrounding grass.' (Berndt and Berndt 1993, 235)

In comments on this myth, the Aboriginal narrator, Albert Karloan, said that the fire that dropped to the ground from Whale's neck wound formed flint stones, which were part of the traditional equipment of Aboriginal fire-making in this part of Australia (see Mountford and Berndt 1941, 342-4). Thus here an etiological myth about the origin of fire-producing technology is combined with a myth about how fire

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became generally available in the world through a primaeval murder.

Anthropologists, philosophers and historians of religion have written a great deal about the symbolism of fire as a marker of human culture. Because possessing and controlling fire are actions that are seen to differentiate humans in a natural state from humans with culture, fire in most societies has multivalent symbolic meanings.[ii] In many Aboriginal societies the notion of exchanging women in marriage between social groups is expressed symbolically in terms of exchanging or giving fire from one group to another, and sexual misdemeanours may also be expressed with reference to the burning properties of fire (cf. Berndt and Berndt 1993, 187). In the Burarra language from North-Central Arnhem Land, for example, the noun for fire is *bol*; a verb which is derived from this noun, *bolbolwa*, means to participate in bride exchange (Glasgow 1994, 135). In the same language one can talk about a man who commits incest by saying *bol nula gu-juwuna*, literally, 'his fire has gone out'. The implication here is that if someone commits incest, he nullifies or withdraws from the exchange system upon which social life is constructed. It has been suggested to me that the imagery underlying the equation between fire and human sexuality as regulated by social conventions depends upon the assumption that sex, like fire, needs to be steered in the right directions, otherwise participation in the network of sociality based on affinity will be extinguished along with the camp fire that is a living symbol of it.[iii]

One of the most important uses of fire in traditional Aboriginal society, both symbolically and practically, is in ritual and ceremony. There is no doubt that all Aboriginal cultures were and still are deeply religious and express their relationship to the land, to the ancestral spirit beings and to their own human ancestors through complex ceremonies, in which the performing arts of song, dance and visual display combine to produce theatrical effects. In ceremony, humans approach the divine because, by enacting the behaviour of the spirits of the Dreamtime, they both make contact with the spirit world and at the same time reinvigorate it. It is no accident that, in the Whale myth narrated above, Whale produces sparks of fire when he dances. Dancing is the usual means whereby living things reveal their true essences; when a spirit being dances, it becomes more brilliant, just as a human dancer does when he or she imitates a spirit being in the dance (Morphy 1989).

Aboriginal ceremonies have two major purposes: they mark humanity's relationship to the spirit world and the creator beings who made the cosmos, including humans, and they also mark the stages in every individual human life. Fire is an essential component of all Aboriginal ceremonies for both practical and symbolic purposes. Its practical uses are many, but the most important one is to provide light to the ceremonial ground, for most Aboriginal rituals take place at night. The earliest European artists who recorded corroboree scenes always stress the importance of fire in the ceremonial performance. Charles-Alexandre Lesueur was a member of the Baudin expedition that visited the Sydney region in 1802, where he observed performances that gave rise to one of the earliest known depictions of a ceremonial performance, in which we observe the centrality of fire. [Slide 1, 'Corroboree', Charles-Alexandre Lesueur, charcoal and ink, Muséum d'Histoire Naturelle, Le Havre, No. 16008, scanned from Hunt and Carter 1999, 65] Similarly, S. T. Gill produced an 1845 watercolour of a ceremony around the lower River Murray in South Australia [Slide 2, R. Berndt Collection, Berndt Museum of Anthropology, University of Western Australia], where again a fire occupies central position. Another source of light, which is much valued in these circumstances, and is recorded in the Gill painting, is the full moon.

Slide 1: 'Corroboree', Charles-Alexandre Lesueur, charcoal and ink, Muséum d'Histoire Naturelle, Le Havre, No. 16008, scanned from Hunt and Carter 1999, 65.

Slide 2: S. T. Gill, 1845 watercolour of a ceremony around the lower River Murray in South Australia, R. Berndt Collection, Berndt Museum of Anthropology, University of Western Australia.

Fire, like the lights of a theatre, can be and is managed to produce different kinds of light effects or no light at all. It may be made to flare up suddenly, by throwing grass or leaves on it; or it may be damped down to smoulder and flicker, so that objects, actors or actions are only dimly visible or visible to some participants but not to others. This latter kind of effect is often produced in secret rituals in which it is important that some members of the community hear but not see what is going on (Maddock 1982, 121-141). Dancing and fire go together in Aboriginal performance, as can be seen in a ceremony depicted in the film *Waiting for Harry* (McKenzie 1980), in which we see the celebration of the final stage of a mortuary ritual in the Maningrida area of Arnhem Land. At one point boys and young men cause a grass fire at the edge of the dance ground to flare up while they engage in a spirited Plover dance from the Morning Star clan song series Goyulan. The singer is Johnny Mundrugmundrug.

Although its practical and theatrical effects are undoubtedly the most obvious uses of fire in Aboriginal ceremony, the symbolic meanings that fire has for Aboriginal societies govern its use in a great deal of ritual performance. I have chosen to illustrate this point with reference to a single ceremony that I witnessed and helped to record at Maningrida in 1986. However, the symbolic and actual uses of fire within it are comparable to the semiotics of fire in a great deal of Aboriginal ritual that has been recorded as having taken place in the past and still continues today in many parts of Northern Australia.[iv] Essentially, fire is a marker of change, a liminal element, and fire is also an agent of purification. For these reasons, fire is used to mark transitional points in human life, and in Aboriginal society these are normally concentrated around the individual's initiation into adulthood and his or her death. In some Aboriginal societies, birth and marriage are also celebrated ritually, but less elaborately than initiation and death.

The slides I showed in the live presentation of this paper, some of which are reproduced here, record the events of a mortuary ceremony for an important Maningrida man named Harry 'Diyama' Mulumbuk,[v] who died there in October 1985. Although a funeral ceremony was held for him at the time of his death, some close kin and ritual associates were away at the time, so pressure grew to hold another ritual for him, of the type called *darda*, in January 1986.[vi] The two essential functions of a *darda* relate to the deceased on the one hand and the living relatives on the other. The first function is symbolised through the ritual use of fire to represent the deceased's transition from the world of the living to that of the dead (though not yet to his final resting place among the local spirit beings). Fire is used to burn the material possessions of the dead person in a ritual font, thus indicating that he has no further need for them and (from the point of view of the living) that they will not provide a temptation to attract his wandering spirit to return to the settlement. The second function, the purification of the living and their separation from the pollution of death is symbolised by the use of water to cleanse those who had taken part in the funeral rites and touched the dead body. We shall see that certain songs and dances from the clan song, Morning Star, were chosen (and this was a conventional choice) to accompany both the burning and the washing parts of the rite. Morning Star (Goyulan) is the song owned by the patriclan to which Harry Diyama belonged.

In this part of Arnhem Land sand sculptures depicting clan estates or spirit beings are often constructed for mortuary ceremonies (Clunies Ross and Hiatt 1977), and, on this occasion, three men, Gurrmanamana, his son Gumugun, and Mundrugmundrug, the latter the chief singer of the Morning Star song series, constructed a sand sculpture on the *darda* ground outside Harry's Maningrida house. This sculpture was a schematic representation of Mundrugmundrug's clan estate of Mardang-ajirra, which lies on the right bank of the Blyth River to the east of Maningrida, opposite Harry's estate of Kopanga. This sculpture was a present to the deceased from the three men, and comprised a simple design of two *jok* or ritual fonts connected by a corridor. In one of these fonts Harry's material possessions were to be burned and, in the other, the living were later to wash. It so happens that the song series Goyulan is rich in songs with ritual references (as indeed most Arnhem Land clan songs are), and possesses both a Fire song (*Bol*) and a Ritual Font (*Jok*) song, both of which were deployed on this occasion. [Slide 3 and Slide 4] Mundrugmundrug also sang his Red Ochre song (*Juno*), both as the sand sculpture was being constructed and at the end of the ceremony when it was being erased. Like water, red ochre is a purifying agent for *jowunga* moiety clans from this part of Arnhem Land.

Slide 3: Mardang-ajirra sand sculpture, in front of Harry Diyama's house, Maningrida. Photo: L. R. Hiatt.

Slide 4: The two Goyulan singers Jacky Mirribanga (left) and Johnny Mundrugmundrug (right) at the 1986 *darda* for Harry Diyama. Photo: L. R. Hiatt.

After a good deal of singing by the two Goyulan songmen and two singers of the opposite, *yirrchinga* moiety, clan series Wulumunga, people began to use fire to destroy Harry's possessions. First they pulled down a large bough shade in front of his house, which had been constructed expressly for his funeral some months earlier. It was burned [Slide 5]. Then the singers moved nearer the sand sculpture and Harry's personal possessions were all brought out of his house and ripped up into small pieces. Each man and woman participating in the ceremony took a handful of these 'rags' and one by one dropped them into the right-hand font, in which a fire had been lit. [Slide 6] While this happened, Mundrugmundrug and Mirribanga sang the Goyulan Fire song.

Slide 5: Burning Harry's funeral bough shade. Photo: L. R. Hiatt.

Slide 6: Sorting out Harry's possessions prior to burning them. Photo: L. R. Hiatt.

When everything belonging to Harry had been burnt, those who wanted to be cleansed by water moved to the left-hand font. A hose was run over the crowd in the font and the singers intoned a sacred song about a female creator spirit while several women danced, reenacting her Dreamtime journeyings. [Slide 7-11]

Slide 7: Harry's possessions burning in the foreground, ritual bathing at other end of the sand sculpture. Photo: L. R. Hiatt.

Slide 8: Ritual bathing, the women dancing behind the men. Photo: L. R. Hiatt.

Slide 9: A general view of the 'rags' burning in the foreground jok and the burning poles from Harry's bough shade in the background. Photo: L. R. Hiatt.

Slides 10 and 11: Ritual bathing. Photos: L. R. Hiatt.

In the final phase of the *darda* ceremony people withdrew from the font and smeared themselves all over with red ochre. Four dancers, three of Harry's sons and his sister's daughter, crawled slowly all over the sculpture of Mardang-ajirra to the accompaniment of the Red Ochre song from the two Goyulan singers until the design had been completely obliterated. As a final act of purification, Mundrugmundrug sang two verses of the song Ritual Font (*Jok*), whose words not only refer to the cleansing act of ritual washing but to a purifying mythical wind that blows over the dead person's kin, making everything clean and releasing them from pollution. [Slides 12-14: erasing the sand sculpture]

To conclude this discussion of the importance of fire in Aboriginal ceremony, I refer to two verses from the Goyulan song series, one each from *Jok* (Ritual Font) and *Bol* (Fire), and then comment on the mythological background to their representation of fire.[vii] From the perspective of this symposium, the interesting thing about the Goyulan Fire song is that its sole focus is upon fire's ritual and mythological purpose. Together with the *Jok* song, it acts self-referentially to emphasise the role of fire and other purifying agents in human mortuary ritual and to allude to the mythic origins of fire, imagined exclusively in a ceremonial context. It is difficult to produce a word-for-word translation of the texts of Goyulan songs, but the verses of the Fire song contain a number of phrases and verbal collocations that singers gloss as referring both to current mortuary ritual practice in burning the possessions of the dead in a *darda* ceremony, and to the origin of that practice in the Dreamtime (Clunies Ross and Mundrugmundrug 1988, 31). The first mourner was a Spirit Man (Wangarra), subject of another Goyulan song, who long ago made *Jok*, started Fire in it and danced, because he grieved at the daily death, as it seemed to him, of Morning Star herself as she faded each dawn. Spirit Man instituted fire rituals in order to get Morning Star back, but humans use those same rituals in the protracted process of letting go their loved ones and, at the same time, of separating the living from the dead.

Slides 12 – 14: Erasing the sand sculpture. Photos: L. R. Hiatt.

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APPENDIX: VERSES OF THE GOYULAN RITUAL FONT AND FIRE SONGS

Jok, 'Ritual Font'

go go gaia gaia gaia gaia
bwipwio-rdirdawarla bwipwio
bwipwio-ngurrei jukarr-ngurra
wata jurubarla-warla jurubarla bwipwio-ngurra
bwipwio-rdirdawarla bwipwio-rdirdawarla
birnmala bwipwio bwipwio-ngurra
a jukarr-ngurreio bwipwio-rdirdawarla
jukarr-ngurra-marla warndimulnga
ngurra jukarr-ngurra bwipwio
manarangga kurnda-kurndeio
birnmala wata manaranggam.

GLOSSARY

bwipwio, Buluna blows. Buluna is a purifying wind that blows among the cliffs on Elcho Island, home to Red Ochre.
rdirdawarla, ritual font; 'when I sing im, everybody come and bogey [wash]' (Mundrugmundrug's gloss).
wata, another name of the wind Buluna.

Bol, 'Fire'

runoro-nabo runoro-nabo runoro-naba kalpamba-yerram
kalpamba-yerra marruto-bina wurlurl-langga runoro-nabom
jimarl-marrawurr runoro-nabo kalpambam
runoro-nabo marrai-bibbino dakarl-dakarlbo wurlurl-langgei wiumugo-marruto wargugom.

GLOSSARY

runoro nabo (*naba*), song name of Fire.
wurlurl-langga, fire is kindled and burns up a dead person's belongings in a font. This imitates the action of Wangarra (Spirit Man), who long ago instituted the rite in his attempts to get Morning Star to return to him.
wiumugo, Yanyango name (language to the east of the Blyth River) for Spirit Man.
wargugo, the act of grieving, being in a state of grief (for Morning Star), Burarra: 'wargugo jinania goyulan, wargug'andirra wangarra', 'Spirit Man is grieving for that Morning Star'.

[i] This paper contains images of and references to individual Aboriginal people from the Maningrida area, some of whom are now dead. These images and names may cause distress to relatives or other Aboriginal people from this part of Arnhem Land. Hence care and tact should be used in displaying or disseminating this material. Slide 1 is a scanned image of Charles-Alexandre Lesueur, 'Corroboree', c. 1802, charcoal and ink, Muséum d'Histoire Naturelle, Le Havre, in Hunt and Carter 1999, 65; slide 2 is a watercolour (1845) by S. T. Gill of a ceremony around the lower River Murray, now in the R. Berndt Collection, Berndt Museum of Anthropology, University of Western Australia, scanned from the dust jacket of Berndt and Berndt 1993; slides 3-14 were photographed by L. R. Hiatt at Maningrida, Northern Territory in January 1986.

[ii] For a thorough study and interpretation of Aboriginal fire myths in structural terms, see Maddock 1970.

[iii] Personal communication from L. R. Hiatt, to whom I am grateful for these suggestive remarks.

[iv] A fuller description of both the ceremony in question and the songs and dances performed there is to be found in Clunies Ross and Mundrugmundrug 1988, 7-9 and 30-33.

[v] The Harry of *Waiting for Harry* (1980). Harry was his English name, Mulumbuk his Aboriginal name, and Diyama a nickname given to him on account of a song he had once composed on the subject of the shellfish *Tapes hiantina*, called *diyama* in the Burarra language. The name Diyama was preferred in actual use, as Harry's given name was too close in sound to the name of another, deceased community member.

[vi] *Darda* is only one of the complex stages of mortuary ritual in this region of Arnhem Land, and has been described by Hiatt 1965, 53-4: 'The Gidjingali practised a double disposal of the dead. First they buried the corpse in a shallow grave or exposed it on a tree platform. A few hours later men brushed with leaves those who had been near the body, a ceremony called *mandjar*. Then after a week or so members of the deceased's community burned some of his possessions and poured water over his close relatives. This ceremony was known as *dada*. Months later folk recovered the dessicated bones and brought them back into the community in the *bogabod* ceremony. A close relative, such as the widow or widower, retained the bones for several years. Finally, during the *laragan* ceremony, they were placed in a hollow-log coffin, which was buried or left standing upright in the ground.'

[vii] For the cassette tape recording, see *Goyulan the Morning Star. An Aboriginal Clan Song Series from North Central Arnhem Land*, sung by Johnny Mundrugmundrug and Jacky Riala, accompanied by George Ganjupala, didjeridu, edited by Margaret Clunies Ross (Canberra: Australian Institute of Aboriginal and Torres Strait Islander Studies, 1988), Side 2, bands 20 and 21. Band 27 on Side 2 is of *Juno* (Red Ochre). The glossed song texts are in the Appendix.

The Bastard Country: Fire on Stage

Professor Malcolm Gillies[1]

Australian non-indigenous arts have been variously engaged with fire. The theme of bush fire certainly runs strongly through Australian poetry and prose. The visual arts, especially painting and photography, have been much caught up with representation of the Australian landscape -- "The landscape is something I can hang my coat on", once commented Fred Williams[1] -- and so these visual arts, too, have been frequent in their portrayal of fire's effects upon the national landscape. Australian performing arts -- and I am thinking mainly of drama, ballet, opera and music -- have been less sustainedly concerned with the Australian experience of fire, perhaps because of the longer and stronger lingering of European traditions in these arts (which has sometimes translated into an explicit avoidance of their Australian circumstance altogether). Such art forms, at least the sound-related ones, are also, of course, inherently less representational. Despite the existence of some Australian music "landscapes" as far back as Isaac Nathan in 1840s Sydney, music historians still tend to look to 1940s Sydney, and to John Antill's symphonic ballet *Corroboree*, for the first distinctively Australian musical work. Of course, Antill's claimed Australianness owed much to its overtly Aboriginal theme, which culminated in a "Procession of Totems and Closing Fire Ceremony".

Today I consider two recent Australian musical works which represent aspects of fire: Michael Whiticker's *After the Fire*, a work for solo amplified harp written in 1991-92, and Colin Brumby's opera *Fire on the Wind*, dating from 1988-91, although planned from as early as 1974. Whiticker drew his inspiration from a visual source, *After the Fire* of 1968 by Fred Williams. Brumby has, on the other hand, looked for the source of his operatic libretto to a play of Anthony Coburn from 1957 entitled "The Bastard Country", later retitled "Fire on the Wind".

First, Whiticker's work for that Cinderella of musical instruments, the harp. Where the harp has been placed centre stage in classical music, it has tended to be given "nice", even celestial, music. The harp, after all, is the traditional instrument of angels. Whiticker wanted something different, something which might cause shock to his audience through its "ugliness".[2] About the inspiration of Fred Williams' paintings Whiticker claimed in introducing the work's score:

> My title then is taken from a series of works which the artist painted following a bush fire in the Dandenongs in 1968 where he then lived. What especially excited my imagination was experiencing in his paintings an acute observation of the different states of the bush in the days following the fire: smoke belching from the occasional gum; the haze left wafting across the blackened landscape; the ground crackling and dry underfoot; rain arriving, dirtying and soaking the bush. Williams' fascination with the speed of regeneration of the bush was also important to me. As the haze clears, the clean blue of the sky is a symbol for me of the new growth shooting through the earth (a promise of the life bursting inside this supposedly dead landscape).[3]

How such vivid visual stimuli are actually transformed into the musical substance of Whiticker's *After the Fire* is something which the composer does not explain. How, after all, does one represent a tree or the "clean blue of the sky" in music? Such matters are, as ever, largely left to our listening imaginations. However, it would not be unreasonable to conceive of this work as one of progressive images leading from the environmental death caused by the fire through to nature's regeneration, triggered by the arrival of rain. Whiticker's work is, then, definitely "after the fire", not "the fire and its aftermath".

After the Fire is a fascinating work, at least to me, because my listening imagination does hear in it many Australian bush sounds, particularly the "ground crackling and dry underfoot" which Whiticker mentions in his "Introductory Note". His success comes from the avowedly theatrical approach to this fourteen-minute-long work, which he wrote for the virtuoso Sydney harpist, Marshall McGuire. McGuire does much more than just pluck his harps' strings in time-honoured angelic fashion. Whiticker demands not only that the instrument, but also that the player be amplified (through the use of a

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lapel microphone). He is concerned that the audience be able to hear the player's breathing and body movements. A floor microphone is also required "to amplify the pedal and feet movements [of the player] as much as possible".[4] Whiticker's theatricality is furthered through the dictation in the score of a plethora of very specific playing techniques. The instrument is plucked, hit, rubbed, bowed, dampened and (using the pedals) "crashed".[5] These many demands turn his scores into a notational jungle not for the faint of heart. The resultant effects are, however, fantastic. Here are three short examples:

1. Score cues 7-8 juxtapose unpitched sounds of fingernail and hand on the instrument's wooden soundboard and pitched sounds (played on the harp's strings) involving sliding fingers and striking of the strings.
2. Score cues 26-27 illustrate the sounds caused by using a wooden skewer as a bow, in conjunction with using a glass or metal slide along the strings.
3. Score cues 39-41 explore darker sonorities of the instrument, where traditional gliding sounds, created by wiping the hand across the strings, are situated among darker, low "clumps" of notes.[6]

Whiticker's *After the Fire* is a deliberately "destructive" and technically exploratory work. It involves "collisions of musical materials and gestures" which are, as Whiticker himself says, not "safe".[7] This work seeks to shock the listener in a similar way to the shock caused by those Dandenong Ranges fires of 1968 which came within one hundred metres of Fred Williams' own home at Upwey, and inspired his wonderful succession of "Fire" works. As Patrick McCaughey describes: "It was a terrifying experience ... like 'living in a war' ... the experience was so intense and so particular that it had to be exorcized [by Williams] once and for all".[8]

Fires in the Dandenong Ranges were also an inspirational force for the other work I shall touch upon, Colin Brumby's opera *Fire on the Wind*. As a five-year-old living in Glen Iris, Brumby had been terrified by the graphic press photographs of the Black Friday fires of January 1939. These fires impressed upon him the very power of nature, where one's destiny could be determined by a momentary change in wind direction.[9] Brumby's childhood apprehensions were recalled around 1960 when he saw Anthony Coburn's play in an Elizabethan Theatre Trust production in Brisbane.

Fire on the Wind is set in a fictitious northern Victorian town, Jimpna, in the summer of 1950, when, according to Coburn's Foreword to the play, the region was experiencing the "hottest drought they have known since 1939".[10] Fire is a background source of menace throughout the opera's plot, somewhat as Verdi might use a smouldering volcano as a constant source of operatic tension or as the prospect of fatal illness hangs over a host of nineteenth-century dramas. The on-stage action of the opera concerns intertwined themes of revenge and love. It centres around an Australian returned serviceman guilty of wartime murder in Greece (and, all in all, "a bit of a bastard"), and a second major character, a passionate Greek wanting "compensation" for that murder, curiously by marrying the ex-serviceman's daughter! As these on-stage passions ebb and flow, so does the off-stage menace of fire grow and recede according to the prevailing winds. And the tonal stability of the musical texture fluctuates according to both themes. There is no fire motive or dedicated fire music, but rather a skilful coordination between the on-stage and off-stage tensions of the plot and the sense of musical surge and repose.

The menace of fire is introduced at the very start of the opera, which opens upon the town's barber engaged in a call over a faulty telephone line. The difficult, slow gathering of information and the one-sidedness of the phone conversation (the other side being represented by brief musical interludes) rapidly set the audience on edge. Here is the opening of Brumby's libretto:

What's that you say? You'll have to speak up; I can't hear a word you say! ... A fire, you say, a fire? ... Where did you say it was? I can't hear a thing you're saying; wait till I give this a bang! ... That's better now; much clearer ... No need to shout like that! Now, what's all this about a fire? And where did you say it was? ... Up on the ridge, and not much smoke? Can't be doing much harm then. Why don't you watch it and ring again if it seems to be getting away? ... That's the idea; keep an eye out and phone if you need any help ... I'd round the fellas up from here. But sounds like there ain't much need.[11]

Throughout the opera the fire lurks there, up on one ridge or another. Early in Act II, as the Greek and his new wife (yes, the ex-serviceman's daughter) wish to set off for their honeymoon they are warned that the winds are changing, and that where they intend to go looks set to be burnt out. Eventually, the final scene bring the opera's coordinated on-stage and off-stage denouements. The returned serviceman is strangled by the Greek. As his body drops, "there is a tremendous clap of thunder, and it begins to rain".[12] The fire danger has passed. The opera's villain is dead. The two lovers join in a joyous duet:

> Thank God the storm has broken,
> Thank God it's brought on rain;
> Pray we don't have to endure
> A drought like that again.
>
> Now that the rain is falling,
> Now that it's brought relief,
> Pray that we, in each other,
> Will find a new belief.
>
> Gone now is the danger,
> Gone from us now is the threat;
> Pray that we will recover
> And, in time, in time, forget.[13]

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[1] As quoted in the 1989 Film Australia video *Patterns of Landscape: Fred Williams, 1927-1982* (dir. Christina Wilcox).

[2] Whiticker, "Introductory Note" to the unpublished score of *After the Fire*, held in the Australian Music Centre, Sydney, p. 1.

[3] Whiticker, "Introductory Note", p. 1. Reproductions of several of Williams' 1968 "Fire" works, such as *Fire Approaching*, *Burnt Landscape*, *Landscape with Burning Tree* (all oil on canvas), as well as *After the Fire* (goache), are found in Patrick McCaughey, *Fred Williams* (Sydney: Bay Books, 1980), pp. 201-3.

[4] Whiticker, "Introductory Note", p. 2.

[5] See, for instance, occasional score instructions to "hit string with skewer" and "rub hand / finger quickly up and down length of strings".

[6] A recording of McGuire's performance of this work is found on the ABC Classics compact disc, *After the Fire*, of the Australian contemporary-music group Elision.

[7] Whiticker, "Introductory Note", pp. 1-2.

[8] McCaughey, *Fred Williams*, p. 200.

[9] Interview with the author, 5 September 1999.

[10] Unpublished text, held privately, p. [2].

[11] Unpublished piano score of *Fire on the Wind*, copy held in the Australian Music Centre, Sydney, 1 / 1 / 1-5.

[12] Piano score, 2 / 2 / 39.

[13] Piano score, 2 / 2 / 40-44.

Returning to Ashes

Dr Peter Read[1]

1 THE FIRES

On 16 February 1983 the temperature in southern Victoria rose to 43 degrees. In the ranges west of Melbourne people were particularly nervous.[i] A bushfire a fortnight earlier had come perilously close to the towns of Macedon and Mount Macedon. Water was desperately short. On this blustery day a second fire from the north seemed to have bypassed the town. Nevertheless many families had packed their cars with precious belongings and were awaiting the signal from the fire station to evacuate to the nearest shelter. For families in the top end of Macedon the designated shelter was the Macedon Family Hotel.[ii]

A few hundred metres from the hotel lived Peter and Sue Boekel. They were schoolteachers at Gisborne but rented their timber dwelling from the Education department. It was an older place, two bedrooms and a sleepout. They had been in the town for a year and were beginning, they said, to put their roots down. Macedon seemed a sleepy town. Peter Boekel joined the amateur Dramatic Club, but the Boekels were not pub-goers; apart from the parents of some of the children whom they taught, they did not mix much with the townsfolk.

On 16 February Peter Boekel was returning from a school excursion, exhausted by fractious children and an overheating bus engine. Sue waited for him at home in the thickening smoke. It was obvious from the confused media reports that a national calamity was occurring - but where, and where next? From the fragmentary news it seemed likely that the fire would bypass their town, but Gisborne, downwind from the prevailing gale, was threatened. Should they evacuate? The Country Fire Authority had advised them to wait for the signal from the Fire Station siren. A fire truck raced by to evacuate one or two families. That was puzzling as well as worrying. By 7pm it was apparent had shifted from the north to the south west. The 3 km front had widened to fifteen km and was racing at sixty knots towards the town. The wind shift probably had saved Gisborne but Macedon, in the path of the freshening winds, stood directly in the altered firepath. The Boekels' home would be among the first to be consumed if the wind did not abate. Still there came no word from the firefighters at the station who, had the townsfolk known it, were occupied elsewhere or were cut off by flames. The fire station was empty.

Smoke and cinders increased. At 7:30pm Peter and Sue Boekel, alarmed by the ever thickening smoke and the ominous roaring from over the hill, decided to make for the designated safe zone. As they hurried to the Macedon Family Hotel the tops of the pine trees upwind of their home were blazing. They parked the car piled with their most precious personal items opposite the fire station and scrambled into the hotel.

Across the road in the Macedon post office, postmaster Paul Gray sat at the Country Fire Authority two way radio. There was no longer much he could do. The fire station was empty, the major firefighting equipment cut off at Bacchus Marsh. His post office was now the headquarters of the Macedon fire service. The town was defended only by a tanker and a couple of trailer units parked outside the house. Residents frantically radioed to ask what to do. Paul Gray replied that they should judge their own circumstances: if they had the equipment and personnel to save their homes they should do so; if not they should leave at once.

Paul's wife Eleanor was calming a large number of people taking shelter in their home. Two of her own three children, their tiny treasures already in the car, were ready to run across the road to the hotel but the third, Yvonne, was keeping company with an expectant mother in a house nearby. The power failing, Paul switched to the battery amid the undefined roar from the direction of Gisborne. The wind was fierce and the sky boiling red as Eleanor gathered up her elderly charges and escorted them across

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the road to the hotel. She returned for the kids, praying that Yvonne was safe and stood by the hotel window, watching her darkening home, pondering the wisdom of returning to fetch the wedding albums. Where was Paul? Where was Yvonne?

Paul Gray continued his desperate messages. At about 7:50pm the room was abruptly lit by a weird orange glow. The oak tree overhanging the house was burning. *This is Macedon Station closing down. I'm going across to the pub.* Paul Gray ran across the road and hammered at the locked doors of the hotel.

Eleanor Gray saw her husband arrive. Worried sick at Yvonne's disappearance, she stared through the window as the wind howled and the trees bent almost horizontally. The fire station was ablaze. Unlike Peter and Sue Boekel, whose house was on the far side of the rise, they could see their post office home directly opposite. Before her eyes *that beautiful old building,* ninety years old, their own home, began to burn as embers from the blazing fire station swirled around its timbers. *The first corner hurt terribly. It didn't actually draw me but I had to look at it.* The oil tank exploded with a roar that could be heard above the howling of the firestorm.

Three hundred people were sheltering in the hotel, but even at the height of the conflagration new arrivals continued to batter at the door. Each time the door was opened a swirl of ashes, cinders and burning sticks followed the refugee. So thick was the smoke that those not involved in the urgent business lay on the floor. People drawn to the windows saw their cars, each laden with precious belongings, burst into flame. Peter and Sue Boekel remember flames blown parallel to the road by the gale, the asphalt burning, smoking cinders from the ceiling ventilators swirling about the saloon, footsteps thundering on the roof as desperate firefighters fought to save the hotel. By 10:30 watchers saw most of Macedon in ruins and the fire racing towards the town of Mount Macedon.

News arrived that Yvonne Gray had sheltered safely with her neighbour. Shortly afterwards Yvonne herself arrived, white-faced and silent. The first crisis was past. A cool change came with a few spots of rain and the night grew very cold. The danger of fallen power lines made leaving the hotel dangerous. In Sue Boekel's recollection, the *mood was subdued as people realised they'd been devastated and we started to contemplate what we'd lost.* The community emerged from shelter to find a forest of chimneys and twisted tin. Six people had died, more than 400 homes had been destroyed.

At first light Eleanor and Paul Gray drove to Gisborne and soon after returned up the melted road to the wreckage of their home. The intensity of the fire had destroyed almost everything. A single saucer survived of a tea set one hundred years old. Two intact plates remained inside the dish washer which had crashed through the burning kitchen floor into the basement. A glass saucepan still standing on the stove shattered when touched. They found a macabre humour in recognising objects twisted to unfamiliar shapes. Golf clubs bent double, the chandelier without its fitting lying in the rubble at first unrecognisable. The garden swing survived and half the boat, but the caravan was reduced to four mysterious silver wraiths. The post office safe seemed intact but when opened by a locksmith the money and documents dissolved to ashes.

Peter and Sue Boekel were also returning to nothing. As they made their way through spot fires, fallen trees and solitary chimneys *it looked like Hiroshima.* They met a neighbour whose house was still standing, then a firefighter with streaming blood-red eyes. All that was left of their house was the front fence. The water in the plastic fire buckets had evaporated to a third of the volume and the buckets melted to the waterline. The lawn mower was reduced to an extraordinary aluminium puddle. That object must be the sewing machine. That thing must be the glass preserving jars all melted together. *Oh look, there are the pennies which were on top of the oil heater.* Some miniature ceramic clogs were blackened but unharmed. After half an hour Peter and Sue Boekel returned to the hotel to see if anything could be salvaged from their burnt out car to find only some half-melted jewellery. They started to walk to Gisborne beside the crackling powerlines. A shire engineer drove past ignoring their appeals to stop. A few minutes later they met him again confronted by a fallen tree. They helped him move it then shared a ride to Gisborne. That night in Sue's parents home Peter Boekel recalled, *I hit low point.*

Anne Boyd, a book editor and former Dominican nun, lived alone in her house in Ferntree Gully, Melbourne. While holidaying in America in 1993, she received news that her house had been destroyed by fire. Imagining that she would not wish to visit the site, she allowed her holiday to fun its full course to enable her mind to adjust to the shock of a homeless return. By the time she returned her friends had removed the china, glass and other valuables that seemed salvageable. Anne Boyd came to Ferntree

Gully, she relates, numb rather than upset. *Once I got back there I knew I needed to see it, and my instinct was to keep going back to it.*

Now began that process, already experienced by the Grays and the Boekels, of separating once loved objects into those which were to be preserved and those which were to be thrown away. Burnt pages from her large book collection were blowing about the garden and up the street. They would have to go. Anne stepped over the place where the back door had stood: there, unnoticed by her friends concentrating on items of value, were her walking shoes, just as she had left them. She left them in the mud for the demolisher to remove. She threw away other objects which she turned up or which her friends had found: a scrap of her Dominical cloak, spoiled jewellery, pages of books she had edited. *The burnt fragments, burnt and wet, fragments of my best clothes, fragments of things that had been important to me, lying in the mess.* Twenty years of letters, wet and burned down one side were eventually recovered, but it was only when she got to the bottom of the last box that she realised that her diary and guest book, kept for twenty years, had gone for good. So much had gone of the things gathered over the years which had become part of the meaning of her home: a mosaic of neighbours, former occupants, objects touched by associations, the house, the furniture, the view, the actions, the prayers, the meals, the talking.

Peter and Sue Boekel never returned to live in Macedon. Sue remarked:

> We did go back and have a look around but I don't get a pleasant feeling going back. There wasn't anything to see back at Macedon. There were just people building and it was all blackened, and the attraction originally was the bush, which wasn't there any more. There's nothing there to draw us back now.

Paul and Eleanor Gray decided to remain. Friends lent them a caravan. Paul put the matter prosaically: their return to a functioning post office was an urgent business necessity. Eleanor had stronger feelings. Though the ruin was *a horrible charred mess there was this longing to be back on our block.* Within two weeks the block was clear.

> I wish it had been longer. I remember the [fire brigade] boys came in, they had this great big tractor, and they were going to pull [the chimney] down and they hadn't even asked us or anything, and I was so angry and I went out there like a mad woman screaming 'leave it alone'. That was all we had, just a chimney. It's ridiculous now, but that was how I felt. That they'd come onto our block. It seemed we weren't anybody, we just seemed a piece of paper being processed. As if someone died and the body's taken away and it doesn't belong to you.

Eleanor felt herself numb and unable to make decisions. When taken to buy new kitchenware she thought of the century old crockery lost in the fire and had to be persuaded not to choose the first articles her hand fell upon. She was in shock, she thinks, *probably for months and months. You can operate day to day, but it was very hard to get out of bed and face the day.* The Grays erected a screen to protect themselves from sightseers; even so at Easter hundreds of cars streamed bumper to bumper past the ruin. Eleanor Gray felt humiliation, anger and victimisation as she heard the cries. 'Oh there's nothing, no ruins for us to look at. 'Her own charred ruin, her own place of deep personal engagement was also a messy site for others to exclaim over, photograph and forget. Her chimney, a blackened obstacle to the tractor crew, was also the site of collective family memories, a symbol of the past, a reminder of the terrifying trauma and a protector of their precious and fragmentary possessions.

Ann Boyd also found the public exposure painful. Papers and sheet music were still blowing about a month after the fire. Everyone stared as they went past. Vandals threw things about at night and wrote words about the fire on the walls of the smoke-blackened garden shed.

Yet Anne Boyd considered herself luckier than the people evicted from Yallourn, the brown coal mine whose expansion in the 1960s necessitated the removal of the whole town. Yallourn residents could buy their homes to re-erect some times hundreds of kilometres away - old houses on new sites; Anne preferred to have a new house on the old site. Now as she watched the demolition of the old house, a process of renewal began. She cut roses from the old garden for the table in the rented flat. She returned almost every night, at first to look for objects uncovered by the demolishers, later she found *I just wanted to be there.* The ritual of returning seemed to her to match the ritual of the Catholic liturgy: it seemed appropriate and answered a psychological need. She recalled:

> It was a month before the place was demolished so that I came back frequently and walked through[the ruins] time and time again, and it was like a long funeral. I felt I needed to keep coming and looking at it. You'd walk up the drive and there's be...this ruin. Then they took the roof off and gradually they got down to nothing. I felt I had to go through this process of being there and seeing it gradually go down and down until only the floor was there and the actual foundation.

Ann Boyd found that she began psychologically to recover from depression at the moment the builders began constructing her new house. It was to be built to her own design. In the wreckage she recovered a blue, terracotta and white ceramic plate which was bought in Assisi and had hung in her home in London. It became a centrepiece of the new. *There's a pattern, a continuity, a symmetry about that.* A brass candlestick, now stripped of its lacquer, was put on the replaced piano. She began a new photo album which included a triptych of the living room photographed from the same place 'before', 'the day after' and 'now'. These she described as icons, *images of something important.* So were the photos unexpectedly discovered of celebrations in the old house. The views up One-Tree hill and of the evening sky were exactly the same as before. The carport was rebuilt exactly where the old garage had stood. The stumps and planks of the old house were kept for the new combustion stove. A piece of ironwork wrought by a previous owner was recovered and re-erected. *I felt proud of the continuity. This was the first house in this bit of Ferntree Gully, my parents died in the area, they are buried in the cemetery here, so there is a long personal continuity.* Personal continuity followed. Anne Boyd hung the washing on the restrung, almost identical clothesline. *I found that very satisfying.*

2 REMEMBERING THE FIRES

There are a number of destroyed Australian towns, including the inundated Tallangatta, Adaminaby and Jindabyne, which carry little public signage of their previous location or reason for their destruction. The absence of memorialisation is often taken to be the desire of the authorities which inundated the towns to minimise their own role in the destruction. [iii]The destruction of Macedon, of course, was an act of nature. Yet it would be almost as easy for a casual visitor to pass through Macedon and not know that there was a fire that destroyed most of the town, as it would be to pass through Adaminaby and not know that the town had been relocated from a site now submerged. The lack of signage illustrates the tensions felt by and between those who endured the night of terror. It does not illustrate that the former residents have uniformly ceased to care about the town which once was.

The Boekels are part of approximately one half of the Macedon population which chose not, or could not, return, about the same proportion which did not return to live in Darwin after Cyclone Tracy. The fire has become the most frightening event in the lives of Peter and Sue, not talked about much except on anniversaries or when the visitor asks to see those Delftware miniature clogs which became sacralised at the moment when they were extracted from the burnt and melted wreckage awaiting the bulldozer.

Paul Gray was almost unaffected by the loss of his Macedon home. I interviewed him in the coffee shop which he and Eleanor managed in 1994 in down-town Melbourne. Paul was matter-of fact, chatting to me as he carried on the business, a little puzzled that I should be showing so much interest in an event long past. His attitude was, *There was a fire here once, so what?* Of a business necessity he rebuilt and lived on the same post-office site. Though he does not like the reconstructed town of Macedon as much as the old, he has had no bad dreams or memories. He supported Eleanor's suggestion of an Ash Wednesday memorial park only because the empty space was *a dead paddock doing nothing.* Eleanor was much more affected reliving the events during our more formal interview. The anguish of not knowing the whereabouts of Yvonne was deeply enmeshed in the trauma of endangered lives and her witnessing the destruction of the family home.

The way in which the fire is publicly memorialised in Macedon reflects more the world view of Paul rather than Eleanor Gray. By its emphasis on events after the fire, the sign in the park allows detail neither of the event nor of the lost place.

The Ash Wednesday Memorial Park
is dedicated to the determination and courage
of the Macedon community
after the devastating fires
of 16th February 1983.

The plaque mounted on the porch of the front entrance of the hotel reads in part:

Erected to commemorate the valour of the
volunteer firefighters who risked their lives on the
16 February 1983 (Ash Wednesday) in
saving the lives of 300 persons who
sheltered in this hotel from the fires of that night.

In 1992, these plaques, and another in the grounds of the hotel, were the only memorials. Nothing reminded the visitor or former resident of the place that was or the extreme peril the townsfolk endured. A few blackened fence posts and bits of piping in the children's playground in the area on which the Boekels' house once stood are unobserved by almost everyone.

The lack of memorialisation suggests the difficulty of focussing widely differing emotions, illustrated among the four individuals whose feelings I have described, either on the trauma itself or the loss of possessions. Tensions were felt long after the fire between those who endured the fire and those who were not there, those who stayed to rebuild and those who did not, and even between those whose houses were destroyed and those whose survived. The restriction of the public memorials to the heroism of the firefighters and the community after the fire conceals the differences not only between the actual trauma and the loss of place, but also the very great differences in the ways in which individuals have come to terms with both these events. At the time of my interviews, eleven years had passed since the fire. Twenty years passed in Darwin before the city authorities organised the first major, and highly divisive, 'Back to Cyclone Tracy' reunion. Emotions there ranged from a widespread interest in the Northern Territory Museum's emotive display to the anguished question 'Why can't you just leave it alone?'[iv]

Ann Boyd has only herself to satisfy. Though no public sign announces the event, her new house is crowded both with memories and artefacts. Among the most precious possessions in her reconstructed house are those which survived the fire: the candlesticks stripped of their lacquer, the ceramic plate, the dining room table still bearing the marks of objects lying upon it on the night of the fire, the repolished dining room chairs now reduced to stools. Among the Macedon victims, the most highly revered objects are not those which were merely saved by prior removal, but those which were almost destroyed and still bear the marks of the flames. The physical conflagration has transformed them into precious icons of survival.

We have met those who thought a major conflagration was of little consequence, those who returned to rebuild, those who left and prefer not to return to this day, those who are haunted by the event, who prefer to forget, or who can see good in the event. How, amidst such diversity, should counsellors approach the victims of violent and destructive trauma?

The most important distinction to be drawn is between the trauma of the event itself and the loss of place caused by fire, flood or cyclone. Following Cyclone Tracy, the Darwin civil defence authorities were praised for organising the air-lift, restoring essential services and restoring civil control. But they, and the attendant mental-health services have been equally blamed for not carrying through long-term counselling for those who had lost their homes.[v] The loss of place was generally considered to be unimportant compared to addressing the psychological effects of the cyclone itself.

The lapse is to a point understandable. Media interest wanes, new crises arise elsewhere, emergency workers want to return to their bases, public funds decrease. Less justifiable is the attitude which says to the trauma victim, 'You have another house in a better location, what are you complaining about?' Such an attitude has been presented all too commonly to victims of the catastrophe of flood, fire and compulsory acquisition for the construction of freeways. Organisations such as the National Grief and Loss Association recognise that grief at the loss of place may have consequences just as serious for some individuals as the much more obvious consequences of the trauma of narrowly surviving a major conflagration. The lessons I have learned from many people who have lost places of affection to violent destruction, including those whom I have discussed here, is that long term psychological accommodation of such events takes many forms over many years. Members of the Stolen Generations returning home after many years absence similarly react with tears, silence, anger, joy, grief and numbness. Almost no reaction to the loss of a secure and protective place, in my own observations, canbe considered abnormal.

The trauma of fire can not be considered complete when the last insurance claim has been settled and the last victim rehoused. Traumatised memories, like sawdust, can smoulder for years. Unattended for too long, released emotions can be as difficult to control as the fires which caused them.

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[i] The interviews with Peter and Sue Boekel, Ann Boyd and Paul and Eleanor Gray were conducted in 1994. Much of the information in this chapter has been drawn from these interviews. See also P. Read, Lost Places and the Language of Destruction'; *Australian Folklore,*10 (1995).

[ii] Not a great deal has been written by historians on the social and psychological effects of violent trauma followed by the loss of a place of attachment. Among the most important is Tom Griffiths, *Secrets of the Forest,* Allen and Unwin, Among psychologists and social scientists who have written on the subject outside Australia, see Marc Fried, 'Grieving for a Lost Home', in L. J. Duhl ed. *The Urban Condition,* Basic Books, NY 1963, and Gerder M. Speller, 'Landscape, Place and the Psycho-Social Impact of the Channel Tunnel Terminal Project', MSc thesis, University of Surrey 1988.

[iii] Cf. P. Read, *Public History*.

[iv] Cf P. Read 1996, pp. 165 ff.

[v] See Gordon Milne, 'Cyclone Tracy I. Some Consequences of the Evacuation for Adult Victims', in *Australian Psychologist,*12, I, (1976); D. Webber, 'Darwin Cyclone: An Exploration of Disaster Behaviour', *Australian Journal of Social Issues,*11, i (1976), Gordon Parker, 'Psychological Disturbance in Darwin Evacuees Following Cyclone Tracy, *Medical Journal of Australia*, 21 (24 May 1975); discussion in Read 1996, pp. 156-7.

The Personal Experience of Fire

Mr Grant Heading[1]

Fortunately most Australians will never experience genuine fear. I'm talking about the gut wrenching, scared to the marrow fear that grips the body when you're forced to confront your own mortality. And believe me it's a sensation that's very. Very frightening. It's something I've never forgotten even though my encounter with a terrifying bushfire goes back nearly twenty years. And I'm reminded of the trauma nearly every time there's a major fire – where people's lives are threatened or worse still when lives are taken – you can't help but think of those horrific final moments when those poor souls knew they were going to die. They no doubt struggled to find a way out, some desperate way to survive, before finally succumbing.

On Ash Wednesday 1980 I survived and together with my crew managed to capture the dramatic minutes in which our lives and those of a dozen or so volunteer firefighters were nearly engulfed in flames. I still vividly recall the day and most clearly of all I remember how I was overwhelmed by the most basic instinct of all – the instinct to survive – when nothing else matters but saving your life and hopefully the life of someone near or dear to you. Before showing you those pictures I'd like to remind you what the day was like and how we came to be in the middle of the turmoil.

Conditions were as bad as they can get – a howling northerly, searing temperatures nudging 40 degrees and a tinder dry Adelaide Hills. Somehow you just knew a tragedy was in the offing – you could sense it – everyone was just waiting for the inevitable. Smoke was spotted around midday and in no time a huge pall could be seen from where we worked at the ABC building at Collinswood (that's just to the north of the inner city) and that's where I was on standby with my crew. We immediately set off towards Stirling and I must say we were pitifully ill-prepared for what was to follow.

Today all camera crews are equipped with firefighting overalls, fire proof blankets, first aid kits and boots. Sadly there was no such awareness back then and we didn't possess so much as a bottle of water. We were the first television news crew to arrive at the scene – the fire had been going less than half an hour and police had not erected any road blocks – we followed the smoke and stumbled into disaster.

At this point in Mr Heading's presentation he showed the ten minutes of footage that won him and his crew, among other awards, the Gold Walkley for the best piece of journalism in Australia for 1980.

I'd like to revisit some of those events – recall how the tragedy unfolded and miraculously how we survived…I say tragedy because several of those firefighters were taken to hospital with serious burns.

When the trucks stopped on Longwood road just beyond Heathfield we all had a clear view of the fire. You'll recall that it had started in the Heathfield dump with the fierce wind whipping up embers from a previous burn.

The road followed the ridgetop and the leader of the volunteer firefighters obviously thought his team could stop the fire as it came up the hillside.

At this stage the fire was still two or three kilometres away I'd guess but it was advancing at an amazing pace. And this is one of my most striking memories of that day – the astonishing speed at which a fire can move. You think you have time but minutes become seconds and it can be on you the moment you turn your back. Ducking back inside a house for example to retrieve some belongings could be a terrible mistake leaving you with no time or no avenue of escape.

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Within a couple of minutes of stopping on that ridge flames erupted on the slope behind us. The wind had carried embers and cinders from the main fire and blown them straight at us, catching everyone by surprise. In trying to contain this breakout, the firefighters turned away from the main front. An instinctive but dare I say a near fatal move. It's fair to say there was a good deal of panic at this stage because the flames were so close.

Fortunately camera assistant, Duscan Jonic had had the presence of mind to turn the car around as soon as we stopped so that we were facing the direction form which we'd come. I have no doubt that act was the single most important factor in our survival. After all, we now had a means of escape!!

Of course, as the footage shows, the main front roared up the hillside while the firefighters were fighting the spot fire behind us. I can't tell you how terrifying it was to turn around and see that wall of flames 20 or so metres high – without any exaggeration it was a furnace, some sort of hell…as I said in the report we were in the middle of a fire storm. With flames on both sides of us now, the heat was unbearable. The only protection was to put your hands to your face to stop being cooked, all the while trying to look for a way out…a way back to the car. And the wind – it was shocking – as most of you know the heat and flames generate their own incredibly strong vortexes and somehow I felt as though I was being sucked in…and all the while the blinding, swirling smoke, rendered you almost incapable of seeing anything but blurred images. Cinders stung your flesh – I was left with burn marks all over my clothes. Voices told everyone to clear out and as I said earlier in this situation instincts somehow take over.

Through the chaos cameraman Clive Taylor, his assistant and myself managed to make it back to the car. Luckily it started and we were able to get out. The footage shows that the firefighters weren't so lucky. They had to reverse out…an impossible task in the thick smoke and with flames tearing at the sides of their trucks. We made it barely a hundred metres or so before a firefighter stopped us and told us the road ahead was blocked and we'd have to take shelter in the Longwood post office.

We managed to make it inside in the nick of time…there we joined the postmistress who lived on site and one or two other firefighters…another arrived later.

We wasted no time in placing wet towels around the doorways and windows and dousing the vents with buckets of water. But it was absolutely stifling in there. Again, the smoke was terrible – I could hardly see – the smoke so irritated my eyes that they filled with tears constantly and I stumbled and groped around in semi-darkness. But I could certainly make out the flames that licked at the windows. The fire was all around the house now and the wind was howling…it was like being in an oven…the air was so hot it nearly burned your mouth. When that guy burst in with his hair and eyebrows burning and yelling expletives I genuinely thought this might be it!

We just hoped the fire passed before the house caught alight. So intent were we on self-preservation that the pictures we took were almost an afterthought. I still remember that in the middle of this mayhem we all but collapsed from physical and mental exhaustion. It was extraordinary really, for a short while we just stopped and waited…we couldn't do any more, we just had to sit it out and the fear came flooding back. Eventually after perhaps 15 minutes or so we were able to get outside and while it was still smoky and very windy it was infinitely better than being cooped up in the house.

The report to camera that I gave was a spur of the moment decision by the cameraman who rolled the camera, turned to me and without any warning said, 'Just tell it like it was'.

We didn't waste any time in getting back into our car which remarkably was still in one piece and hi-tailing it back into town. I remember contacting the chief of staff and telling him we were on our way back and he said no you can't the fire's still raging and you have to stay put. Using some rather colourful language I told him that nothing could be better than the pictures we had and there was no way we were going through that again.

Just let me recap on a few of the points that I've made and discuss the long term impact that fire had on me.

Really, nothing could have prepared me for what happened that day. I'd seen plenty of pictures of bushfires, read numerous accounts but I was largely ignorant of a fire's incredible destructive force. Having lived through both Ash Wednesdays and with my own house just managing to escape the second, I have a heightened awareness but many people I know in the Hills are terribly complacent and warnings and advice are more often than not ignored.

Firstly, I remember the unpredictability of that fire. Experienced firefighters thought they could stop the fire on that ridge but they hadn't counted on the spot fire that started on top of us and I'm sure they were deceived by the speed of the main front. The flames crowned across the tree tops and covered that two or three kilometres in a matter of minutes. What hope for those with even less knowledge of fire and how it behaves.

Secondly, the horror of being caught in a maelstrom of heat, flames and smoke. Fear takes hold – as I said gut wrenching, adrenalin pumping fear, that grips you and momentarily incapacitates you. It's a terrible feeling and in that situation panic can overwhelm you. It's so important to try to keep a clear head and as we discovered try to leave yourself a way out.

Critically, you need to be prepared for the worst. We weren't and we got away with it. Today, as I said tv crews are very well equipped and should be able to survive if they become trapped. I fail to comprehend how people can live in the hills without adequate fire protection. My house in the hills is surrounded by sprinklers and fire hoses using an independent water source with a large pump – the system saved the house when we were away in the second Ash Wednesday.

Undoubtedly the most enduring memory of that day is looking back and seeing those firefighters trying desperately to escape the flames.

Hopefully mine was a once only brush with tragedy – these men and women confront such situations many times in their volunteer service. They have my utmost respect and admiration. If they don't go and fight these fires who will – how many lives have they saved while risking their own? As a community we should be eternally grateful.

Being caught in a major fire reminds me that when the awesome forces of nature are unleashed there's precious little we can do to stem the tide. I felt so damn helpless and vulnerable.

I covered a few more fires after that…no where near on that scale ad I must admit to a certain reluctance to venture to far. Ash Wednesday gave me a lifetime of experiences and I hope I've been able to give you an insight into what some of them were like.

The International Scene and its Impact on Australia

Dr Wendy Catchpole[1]

INTRODUCTION

Australia's unique, diverse and flammable vegetation creates unique problems in predicting fire behaviour and controlling fire. Australia's eucalypt forests are probably the most flammable forests in the world: prevalent dry conditions give rise to low dead fuel moisture content and a high quantity of vegetation with the potential to burn; the live foliage has relatively low moisture content and high volatile content; and the masses of dead bark give a high potential for spotting. However, many countries, such as Portugal, France and South Africa have plantations of Eucalypts. Countries bordering the Mediterranean Sea, and the US western seaboard, have climates comparable to the southerly coastal regions of Australia, and similar shrubby vegetation. There is every benefit in these cases for pooling our knowledge of fire behaviour with other countries, and learning from their experiences. Some of the joint research that is taking place in areas with shrubland vegetation is discussed below.

We can perhaps also learn from other countries, such as Canada and the US, where the vegetation and the fire problems are different. These countries have developed techniques for warning of severe fire weather, and have determined physically based prediction equations for some aspects of fire behaviour that could be fairly easily modified for Australian conditions. Some of the modifications that have already been made are discussed, and indications are given as to where other adaptations may be possible.

Predicting the effects of the interaction of a large fire with the atmosphere is an exciting new area of research made possible by the advent of faster computers. Mathematicians, physicists, meteorologists and foresters from all over the world are joining forces in this interdisciplinary and international approach to fire behaviour prediction. The possibilities opened up by this advance in research are considered below.

1 FIRE DANGER RATING SYSTEMS

Fire research in the USA began in the 1920's. Indices of Fire Severity were developed to give forest managers warning to be prepared for severe fires. These indices were generally based on vegetative stage, humidity and wind speed. Fuel moisture contents for the last few days (measured by indicator sticks) were also included to give an indication whether the larger branches and deeper forest litter were potential fuel. In the 1940's and 1950's each of the regions of the US Forest Service was using its own index, and had developed a table or meter for use by fire managers. Australian fire researchers closely followed their North American counterparts. The McArthur forest meter, widely used in Eastern Australia today, is based on the meters used in the USA in the 1950's. The Australian pioneer of fire research, Alan McArthur, developed his grassland and forest fire danger indices to be indicative of the probability of ignition, the expected spread rate and the difficulty of containment (McArthur 1963, 1966, 1973 and 1977). These indices are used throughout Eastern Australia with varying amounts of satisfaction, and they are heavily entrenched in the ethos of fire management and control.

The McArthur indices are specific to vegetation type, and are dependent on temperature, humidity and wind speed. The grassland index includes the percentage of dead grass (known as 'curing'), and the forest meter includes a 'drought factor', as shown in Figure 1. The drought factor indicates how much of the fuel is dry enough to burn, and it increases as fuels dry out after rain. It is a function of the time since last rain, the amount of rain that fell, and the Keetch-Byram drought index (KBDI). This drought index is an indicator of how much moisture content is required to saturate the soil. It decreases with rainfall, and increases with evapo-transpiration. It was developed in the Southeast USA and imported to

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Australia (Keetch & Byram, 1968). Some fire agencies, realising its inapplicability to the more arid Australian conditions, use the Soil Dryness Index, developed in Tasmania (Mount 1972) as an indicator of drought.

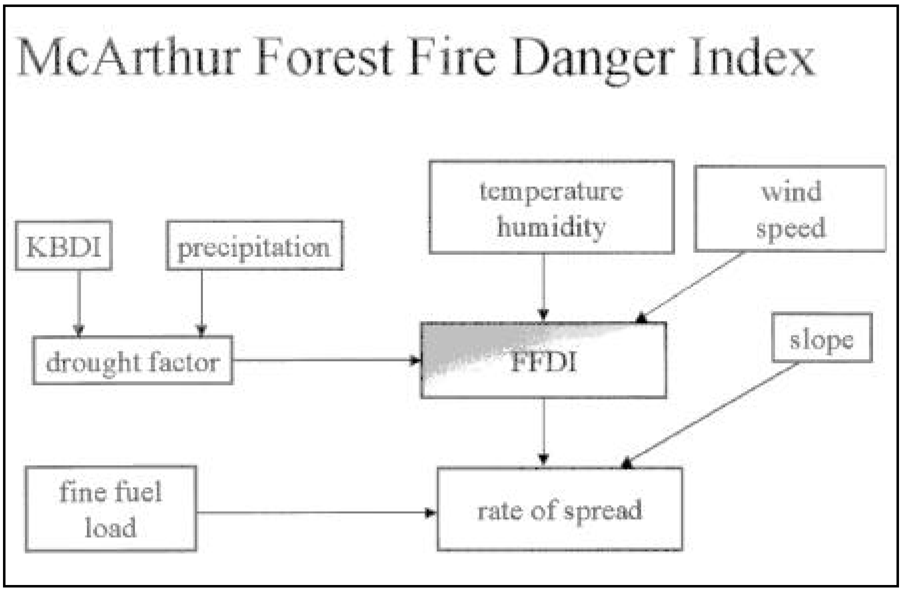


Figure 1: The structure of McArthur's Forest Fire Danger System.

The McArthur indices combine present weather with the potential of the fuel to burn, given by the weather in the past few weeks. Spread rate is predicted as the product of the relevant McArthur index and the fuel load (fuel weight per unit area). The Forest Index is indicative of spread rate with a fuel load of 12.5 tonne/hectare. Probability of ignition and the ease of control are thought to depend on the same combinations of temperature, humidity and wind speed as rate of spread. As fire spread rate is assumed to depend on the fuel load, predictions of spread rate will vary considerably between wet and dry forests, and young and old forests, for the same fire danger index. The indices are used to give an indication fire danger over a large area, and are not specific to a particular area. They describe the relative danger from day to day.

The McArthur fire danger indices apply only to forest and grassland. For different vegetation types (such as heathland, moorland or mallee shrubland) new indices need to be developed. This has been done in Tasmania for the widespread buttongrass moorland vegetation (see Marsden-Smedley *et al.* 2000). If indices continue to be developed for more vegetation types, basing decisions on the resulting plethora of indices may give the fire agencies some headaches.

A more systematic, but similar approach to the McArthur system, is used in Western Australia. Here the result of years of fire behaviour experience has been condensed into the Forest Fire Behaviour Tables (Sneeuwjagt & Peet 1985). The indices used are the expected spread rates in forest types with standard fuel loads. There are 2 forest types for which fire danger indices are calculated, the northern jarrah dry sclerophyll forests, dominated by *Eucalyptus marginata*, and the southern karri wet sclerophyll forests, dominated by *Eucalyptus diversicolor*.

The fire danger systems in Canada and the USA are far more complex. The Canadian Forest Fire Behaviour Prediction (FFBP) system (Forestry Canada Fire Danger Group, 1992) is centered round weather indices that apply to all vegetation, unlike the Australian indices which depend on vegetation type. Spread indices and intensity indices, which depend on vegetation type, are calculated from these weather indices. The concept of fireline intensity was developed by the US scientist, George Byram, in the 50's (Byram 1973). It is the heat given off per meter of fire line, and is a function principally of spread rate and available fuel load. It affects flame length, suppression difficulty, and vegetation damage.

Fire prediction equations in the Canadian FFBP system were developed from experimental fires and wildfires, by relating observed rate of spread to a weather index known as the ISI (Initial Spread Index). Some years ago New Zealand adopted the Canadian system. New prediction equations were needed to determine fire danger in the flammable shrublands surrounding the valuable pine plantations. The New Zealand experience in adopting the Canadian system has highlighted problems with using the same weather index for all vegetation. The ISI is calculated from functions of the Fine Fuel Moisture Code (FFMC), and the 10m-wind speed. (The FFMC is related to the moisture content of the dead fine fuel.) Spread rate is then calculated for each vegetation type using a complicated function of the ISI with different parameters for each vegetation type. Some of the relationships between spread rate and ISI are shown in Figure 2. The system was developed for the coniferous and moist deciduous forests of Canada. The problems of using this system in the relatively dry shrublands of New Zealand are discussed in Fogarty *et al*. (1998). Firstly the FFMC responds too slowly to reflect moisture content in the more rapidly drying open shrublands. Secondly, unlike spread rate in forests, spread rate in shrublands does not seem to have a strong response to changes in the moisture content of the dead vegetation. While the former problem can be overcome by introducing a FFMC specifically designed for shrubland and grassland, the latter problem seems insurmountable. It appears that the Canadian system is too inflexible for importation to vegetation types in more arid areas.

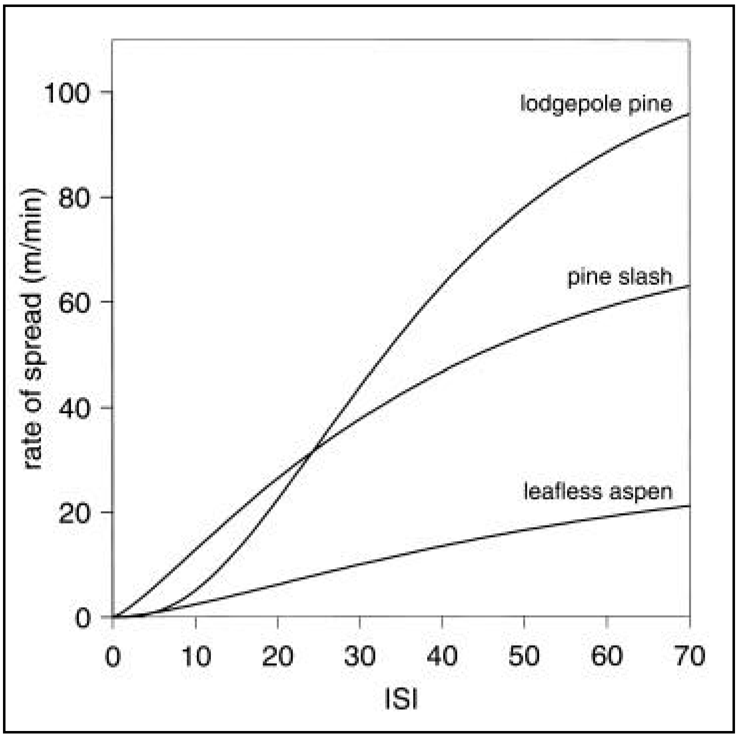


Figure 2: Three of the Canadian Forest Fire Behaviour Prediction System equations for rate of spread in terms of the Initial Spread Index.

In the late 1950's the US Forest Service declared the need for a national fire danger rating system to stem the confusion arising from the many different regional systems in an era of expanding communications. The resulting US National Fire Danger Rating System (Deeming *et al.* 1978) is complex, and requires complex weather and fuel information. A simplified version of the system is shown in Figure 3. It provides 3 major indices. There is an index (known as the Spread Component) based on expected spread rate. The Spread Component may be thought of as being similar to the McArthur Fire Danger index for a given fuel. Another component, known as the Energy Release Component, gives the energy released from unit area of the burning zone. This is calculated from the heat yield of the fuel (which is fairly constant for natural fuels) multiplied by the weight per unit area of fuel available for burning. The Energy Release Component is multiplied by the Spread Component to give a Burning Component that is a function of the expected intensity, and is proportional to the expected flame length. 20 standard fuels are used to describe the US vegetation, and indices can be calculated for each fuel type.

A useful indication of fire behaviour is given by plotting the Spread Component and the Energy Release Component together on a chart, called a 'haulage chart'. The term 'haulage' refers to the equipment that needs to be 'hauled' in to fight the fire. This idea could be used in Australia to help us think about the separate elements of fire danger. In Figure 4 spread rate is plotted against available fuel.

The lines of intensity (assuming a heat yield of 18,000 kJ/kg) border the categories of Low-Very High fire danger given in Cheney (1981). Expected fire behaviour in each of the intensity regions is shown in the figure.

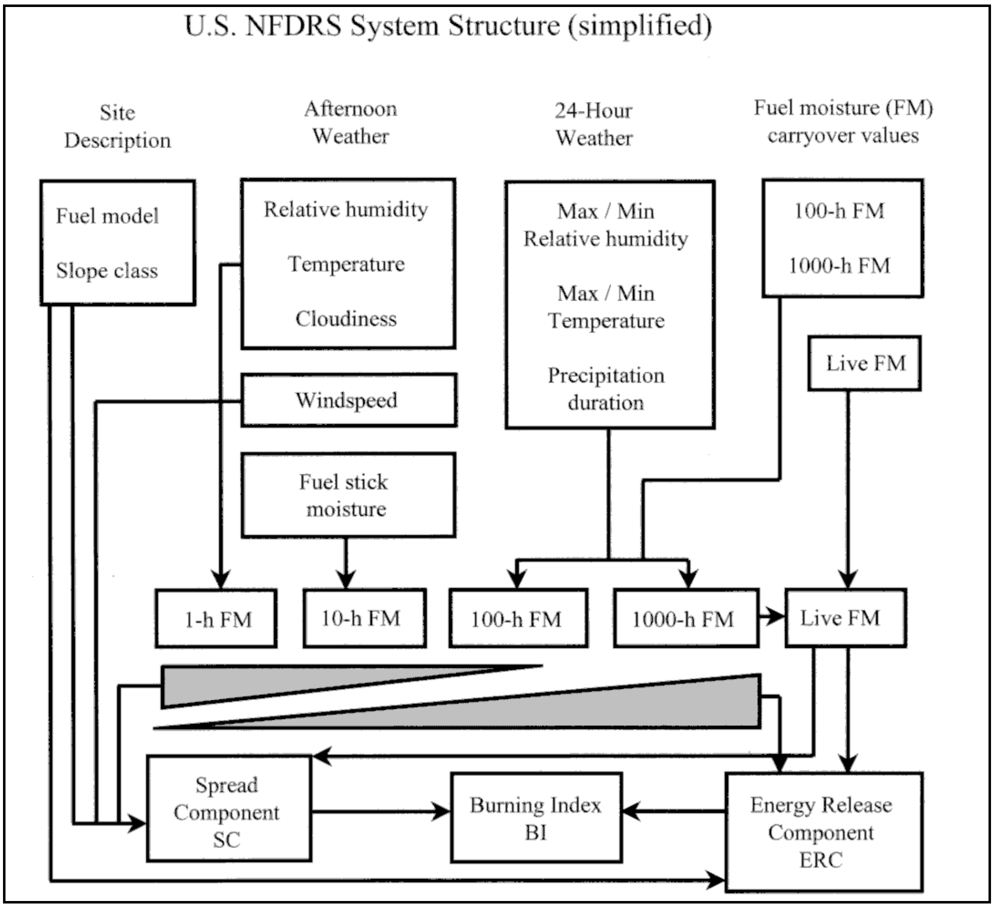


Table 3: A simplified view of the US National Fire Danger Rating System. (Taken from Andrews and Bradshaw (1997), Figure 3)

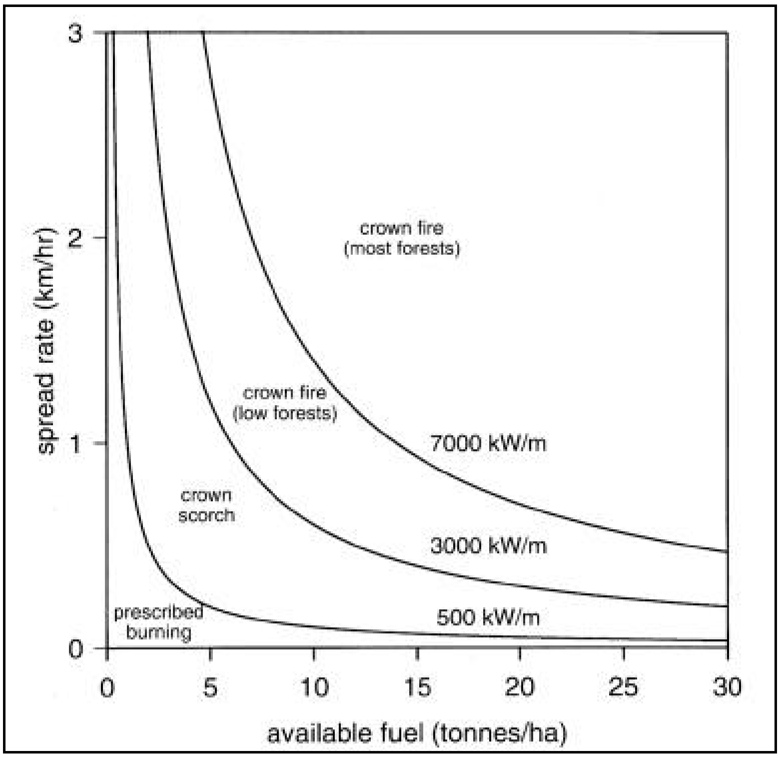


Figure 4: Intensity curves for forest fuel indicating expected fire behaviour in the different intensity regions. Intensity curves are calculated assuming a heat yield of 18,000 kJ/kg.

The probability of ignition of a fire depends on both the probability of a source (called the risk) and the probability of ignition from the source (called the hazard). Sources may be lightning, burning embers or human caused ignitions. The risk varies spatially and temporarily. Areas close to town in school holiday time, for example, may have a particularly high risk. The US Forest Service has developed two Fire Occurrence Indices (man-caused and lightning-caused), combining the risk and the hazard, to describe the probability of ignition (and subsequent fire spread) from lighting and human cause (see Figure 5). Note that the Ignition Component (the hazard) combines the probability of ignition with the probability that the ignited fuel becomes a reportable fire (a function of the spread component). We should consider whether such indices would be useful in Australia.

Some fire authorities have considered these ideas, and have looked at overlaying various layers of risk in their areas using a GIS system. The problem is how to combine these layers into a meaningful figure that fire managers can use. Here, I believe we should be looking at a risk management approach where we consider the probability of large fires and their potential cost. Then the amount of resources required may be estimated in terms of expected losses. It is hard however to put a cost on human life. The idea of separating the risk from the hazard is fundamental to this approach. Ignitions from ignited cigarettes thrown carelessly from a car window are much less likely than ignitions from carelessly abandoned campfires (see Weber 1999). But the probability of an ignition also depends on the number of cigarettes tossed away carelessly compared with the number of abandoned campfires. In the risk management approach we also need to include the probability of a successful initial attack, which will be much less on windy days, in heavy fuels, an on days when resources are stretched.

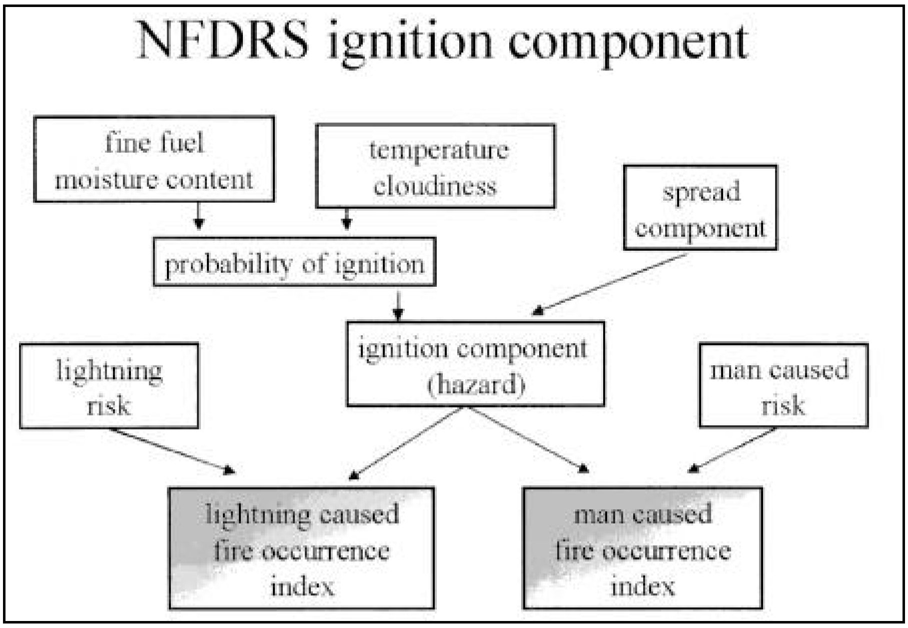


Figure 5: The ignition components of the US National Fire Danger Rating System.

2 FIRE BEHAVIOUR

2.1 Spread Rate

Fire researchers in Australia and Canada are lucky in having large areas of uninhabited land, which enables them to burn experimental fires. These fires can be analysed to obtain fire behaviour predictions in terms of wind speed, temperature, humidity, fuel characteristics and topography. McArthur's approach was to predict spread rate from a Fire Danger Index, fuel load, and slope. Recent research workers have developed equations for spread rate in terms of fuel and environmental variables and then predicted fire danger in terms of spread rate (see, for example, Marsden-Smedley *et al.* 2000). Predictions of spread rate are generally based on experimental fires supplemented by wild fires. There is long history of experimentation in which CSIRO Forestry and Forest Products has played a leading role. Prediction equations have been developed for a variety of vegetation complexes: grassland, forest and shrubland (see Figure 6) but there is much work left to do.

A few years ago fire researchers from 5 states of Australia, and from New Zealand, formed an informal group known as the Heathland Fire Behaviour Group. The researchers are collaborating to study heathland and shrubland fire behaviour, and to share data and resources. Tentative prediction equations for spread rate and flame length are being tested in the field (Catchpole *et al.* 1998). The shrubland vegetation in Australia has similarities with shrubland in other countries with Mediterranean climates, and this has been an area where international collaboration is strong. Members of the Heathland Fire Behaviour Group visited colleagues in the Iberian Peninsula last year, and have built up strong collaborative links.

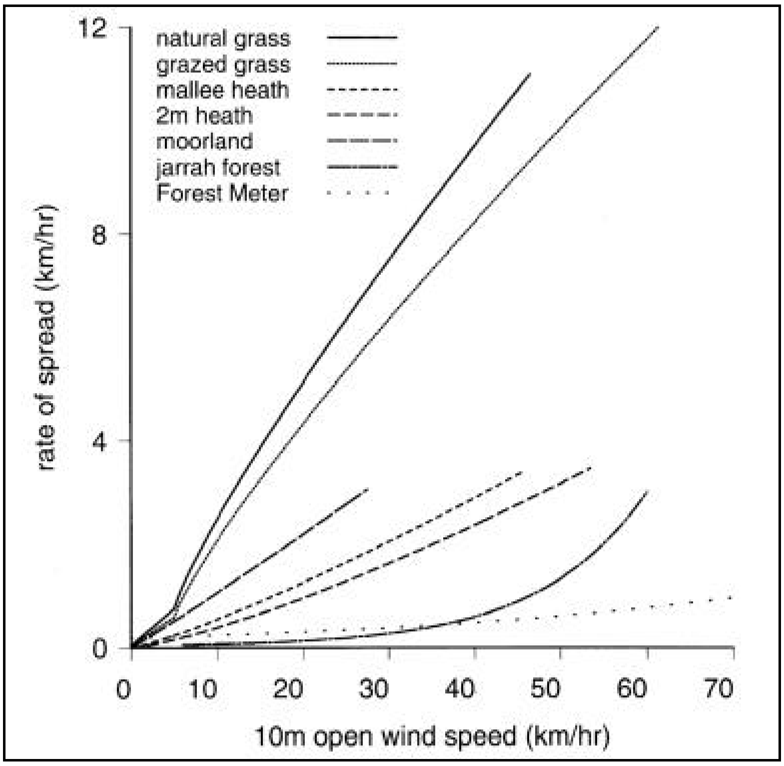


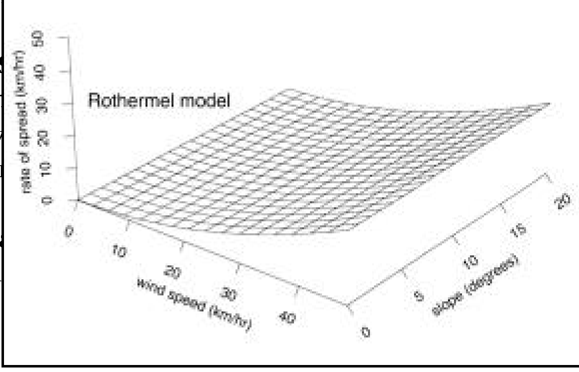
Figure 6: Prediction equations for rate of spread as a function of wind speed (in the open at 10m) for some Australian fuel types. Curves are given over the range of experimental and wild fires use to develop the equations. Conditions: temperature 30°C, humidity 30%, Drought factor 10. Moisture content prediction equations are used for each fuel type. Spread rate prediction equations: natural grass, Cheney *et al.* (1998); grazed grass, Cheney *et al.* (1998); mallee heath, McCaw (1998); 2m heath, Catchpole *et al.* (1998); mature buttongrass moorland, Marsden-Smedley & Catchpole (1995); jarrah forest (8 tonnes/ha), Sneeuwjagt and Peet (1985), equations from Beck (1995); Forest Meter (12.5 tonnes/ha), McArthur (1973), equation from Noble *et al*. (1980).

Fire behaviour research in the USA has proceeded along very different lines. In the late 40's Jack Barrows, a pioneer of fire research in the US, studied 36,000 wildfire reports from the northern Rocky Mountains. Barrows felt strongly that more progress on fire research could be made using controlled conditions to study fire. He lobbied for the construction of a large wind tunnel in which fires could be burned under fixed wind speeds and controlled temperature and humidity. The laboratory opened in 1960 with Barrows as the first lab chief. The US Forest Service hired two engineers, Hal Anderson, and Dick Rothermel to supervise fire research in the tunnel in Missoula, Montana. The physically based approach to fire behaviour prediction of these two engineers determined the path of fire research in the US for the next 30 years.

The idea of a national model, using the concept of energy-balance, and calibrated from a handful of laboratory fires, was visionary and possibly a little over-optimistic. The inclusion of some of Australia's grassland wildfire data probably saved the day. The Rothermel model (Rothermel 1972) is implemented in the BEHAVE fire behaviour prediction system (Andrews 1986, Andrews and Chase 1989). It is still used in the US amid some grumbles that it doesn't work really well far from Missoula. It can however be tuned to fit available fire spread data, and because the relationships of spread rate with wind speed, moisture content and vegetation density are reasonable, it has survived and thrived in the US for 30 years.

The worst aspect of the Rothermel model is that it needs so many different vegetation parameters: for example, fuel loads, moisture contents and surface area to volume ratios of several diameter classes of fuel. The US Forest Service gets round this by using 13 stylised fuel models for grassland, forest and scrub etc. In Australia in the early 80's a few fire agencies (e.g. National Parks and Wildlife Service of NSW) toyed with adopting it (see for example, Kessel & Good, 1980), but compared to the simple inputs of the McArthur prediction equations the vegetation characteristics required were daunting in the species-rich Australian vegetation. Parks and Wildlife Service of Tasmania set out to burn experimental fires to calibrate the model, but found they then had enough information to develop a simple model based on wind speed, dead fuel moisture content and fuel age (see Marsden-Smedley & Catchpole 1995). Dick Rothermel came out to Australia to discuss how the model could be adapted to Australian conditions, but Australia remained skeptical of a laboratory-based model. Research showed the model predictions underestimated spread rate in the densely packed Eucalyptus litter (Burrows 1999), and for vegetation with a high component of live fuel (Marsden-Smedley & Catchpole 1995), and they were far too sensitive to vegetation depth (Gould 1991). The Rothermel model is in the process of being replaced by a more physically-based model developed from over 500 experimental fires, and a wealth of recent field data from all over the world (Catchpole & Catchpole 1999).

The McArthur Meter predictions for spread rate assume that the effects of wind and slope are multiplicative, ie. the effect of slope is the same at a[…]ch uses the new grassland prediction equations (Cheney […]ns fitted to the McArthur Forest Meter by Nobel *et al.* (1[…]an (1997)). The Rothermel model predictions assume th[…]ee Figure 7b). Note that Luke & McArthur (1978) say[…]gh intensity forest fires when the spotting process domi[…]ts have not been tested, as no experimental fires have[…]d speeds. Recent fire experiments on slopes in shrubl[…]d help resolve the issue (see Viegas 1999). The Austral[…]up is liasing with the Portuguese in this work.



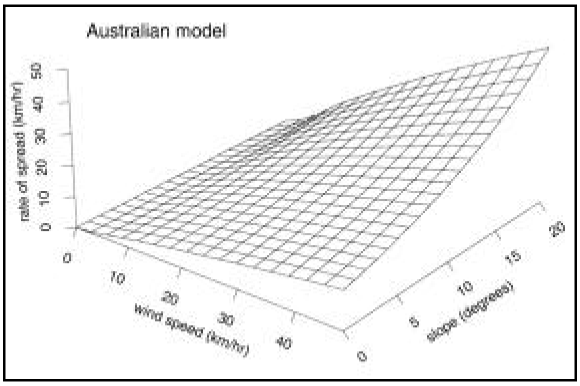


Figure 7. The relative effect of wind speed and slope on rate of spread: (a) US BEHAVE predictions for grassland (Rothermel 1972), (b) Grassland fire behaviour model from Cheney *et al.* (1998), with slope effect from the equations fitted to the McArthur Forest Meter by Noble *et al.* (1980).

Australian fire researchers probably have more affinity for the Canadians who have based their approach on experimentation. The two counties differ in that fire behaviour prediction has been developed nationally in Canada (as in the US), whereas there is no national fire management agency in Australia. Research and management has been largely in the hands of the States, assisted by the federal government in the form of CSIRO. This has the advantage that the State agencies can develop the tools that are important to them. For example, the Country Fire Authority of Victoria has developed tools for tracking frontal weather systems that cause the strong winds and sudden wind changes which are a feature of most of the really bad fire days. Parks and Wildlife Service of Tasmania has spent resources in developing a fire behaviour prediction system for the moorlands that surround the sensitive rain forest. However the lack of a national approach to fire research means that resources are spread thinly and fire behaviour officers in the land management agencies are struggling to find time to spare on research. Thus fire research in Australia may be on the brink of extinction.

Europe has been a late player in the field of fire behaviour research. Now, with EU funding, and the introduction of an International Conference every 4 years, it is finding its feet. In the early 90's Europeans eagerly sat at the feet of the US, Canadian and Australian fire researchers at the short courses in fire behaviour held after the International Conferences, and afterwards they eagerly tried to adopt one of the systems. But the late 90's saw them in the same situation as the Australians in realizing that a lot of experimental fires are needed to calibrate the imposed system, and if opportunities to burn experimental fires are available, a better alternative might be to create their own fire prediction equations. In many cases opportunities to burn are limited and the Europeans are turning to look at physically based models which are discussed later.

Spatial simulation programs of fire spread have been developed in many countries to provide a tool for determining suppression activities, or for training fire fighters. They are run using data from GIS systems. Most of them are based on the fire prediction equations used in the country of origin. One, at least, incorporates 2-dimensional heat transfer equations. It must be emphasized that these systems are only as good as their underlying fire spread algorithms.

2.2 Other Aspects Of Fire Behaviour

In the 70's and 80's fire researchers struggled to find journals that would publish papers on fire behaviour. They were either ‘outside the sphere of the Journal’ or ‘of marginal interest to readers’. Much research was published in land management agency publications and was often poorly reviewed and difficult to obtain. The early 90's brought the publication of the International Journal of Wildland Fire, which made research ideas more widely available. Cheaper airfares have allowed more travel to international conferences, and Australia now has its own biennial conference, which is beginning to get a significant number of international delegates. The Australian National University started up FIRENET, an Internet forum where research workers, managers and fire fighters could exchange ideas, and email services became widely available to land agencies. All this has boosted international co-operation and the exchange of ideas.

Development of a prediction model for scorch height is an example of the way in which research ideas develop internationally. Scorch height is important in determining tree mortality. The Canadian pioneer of fire research Charlie Van Wagner developed a simplistic, but physically based model relating scorch height to fire intensity, wind speed and ambient temperature (Van Wagner 1973). This model was found to under-predict scorch height in Australian conditions (Burrows 1994, Gould *et al.* 1997). Australian researchers first extended the original model to describe the temperature gradient in a wind blown plume above the fire (Mercer & Weber 1994). Gould *et al*. (1997) later modified the assumptions of Van Wagner’s model using a more realistic plume generated by burning clumps of vegetation rather than a plume from a line fire. This model gave better predictions for Australian forests, but calibration is needed to cover a wider range of forest types. Scorch height in Australia has also been shown to vary with season and with drought factor (Wallace 1966, Tolhurst 1995). This probably reflects the fact that leaves are more resistant to damage at the higher live fuel moisture contents associated with spring burns.

When conditions are severe fire may reach the crowns of the trees and the whole vegetation complex burns, killing most of the trees as well as the undergrowth. The Canadian FFBP system predicts the onset of crowning from a model developed by Van Wagner (1977). Van Wagner’s model requires the intensity to be sufficient for the flames to reach the crowns, and the trees to be close enough for fire spread. Modification of the model for the onset of crowning would be difficult for Australian conditions because a fire can run up the thick eucalypt bark, which acts as a ladder fuel. However, the model for critical crown spread could probably be recalibrated for eucalypt forests fairly easily.

Spotting from burning embers is a major problem. Short-medium distance spotting leads to an increase in spread rate, and to ember showers which can threaten housing. Old eucalypt bark from stringy-bark trees, such as *E. obliqua*, or *E. macrorrhyncha*, has a large amount of potential spot fire material that can cause ember showers. Long-distance spotting from candle bark trees, such as *E. viminalis*, or *E. rubida,* can cause new ignitions many kilometres away. The McArthur Forest Meter predicts spotting distance from wind speed and fuel load, but many other factors, such as bark type and age are important.

The brilliant US researcher Frank Albini produced a series of papers in the late 1980's developing a model for maximum spotting distance (Albini 1979, 1981, 1983). In this model the height to which the brands are lofted is calculated. This depends on the fire intensity and the drag on the fuel particles (a function of their size and shape). When the lofting height is known the burning fuel particle's trajectory to the ground can be calculated. The brands will cause a spotfire if they are burning when they reach the ground. Research done by CSIRO Forestry and Forest Products could help modify this spotting model for use in eucalypt vegetation. Drag and burn out times for Australian fuels have recently been determined using a vertical wind tunnel (Ellis 1999).

The scorch height, crowning and spotting models that have been discussed have a physical basis, but the approach is based on 1-dimensional approximations and limited experimental calibration. A complete 3-dimensional physical model incorporating heat, mass and energy transfer, as well as the chemistry of combustion, would allow us to:

i) predict fire spread for all vegetation;
ii) predict all aspects of fire behaviour;
iii) understand the interaction of slope and wind speed; and
iv) understand of the interaction of the fire with the atmosphere.

Complete physical models of fire behaviour are complex and computer intensive. Two approaches are being taken:

a) Numerical solution of the equations of the combustion processes and of heat, mass, and energy transfer close to the fire. This is the approach taken by the Russians, Chinese and French (Grishin 1997, Fan & Wang 1996, Larini *et al.* 1998).
b) On a much larger scale, inclusion of a heat source into a meso-scale meteorological model. This is the approach taken by some researchers in the USA (Clark *et al.* 1996).

In addition to spread rate, a complete physical model can give the temperature profile in the flame and in the plume above the flame. It has the potential to predict ignition and extinction probabilities, and it can be used as a tool to determine firebreak effectiveness.

A two dimensional form of the model developed by Larini *et al.* (1998) was validated in the EU funded EFAISTOS project, in which research workers from University College, UNSW participated. The project was unique in that the same fuel was burned in different laboratories, as well as in the forest, giving an opportunity to test whether laboratory experiments could be used to simulate forest fires. The research consisted of experimentation, radiation and convection measurements, and numerical simulation to try and reproduce the experimental results.

Atmospheric interactions with large fires can cause 'blow-up' fires, where increasing turbulence can cause dramatic increases in spread rate as the convection column builds up rapidly and spotting becomes dominant. Whirlwinds and strong updrafts can produce ember showers over unburned fuel. Turbulent rolls on the leading edge of the fire front may bring sheets of flame in contact with fresh fuel. George Byram, first identified conditions leading to 'blow-up' fires (Byram, 1954). Such fires are more common in the North American conifer forests, but instances have been recorded in Australia on bad fire days (Burrows 1984, Buckley 1990, Tolhurst & Chatto 1996).

Another serious problem, possibly related to the fire's interaction with the atmosphere, occurs when a frontal weather system causes changes in the wind direction. The flank fire becomes the head fire, the fire front is wider, and the spread rate increases enormously. This is a great danger to fire fighters. CSIRO Forestry and Forest Products have recently quantified the effect of fireline length on spread rate in grassfires (Cheney & Gould 1995). Corresponding relationships are needed for forest and shrubland fires.

CSIRO have also found that atmospheric interactions can cause spread rate to be very variable because of thermal activity. Updrafts draw up the convection column and slow the fire. Downdrafts blow the fire outwards and increase the spread rate. The interaction between fire convection and atmospheric thermal activity can intensify the response of the fire to variation in wind speed. This is most marked in grassy fuel under open forests and woodlands where the canopy reduces the wind speed near the flames (Cheney & Gould 1997).

Work done by National Center for Atmospheric Research in the USA in introducing a heat source into a meteorological model may help explain these 3-dimensional effects (Clark *et al.* 1996). Australian scientists have had some involvement in this project, and the Terry Clark has visited Australia to discuss his work with Australian meteorologists. This work may also help our understanding of fire whirlwinds at the edge of large fires. Clark's predictions are being tested in large-scale experimental crown fires undertaken by Forestry Canada in the boreal forests in Canada's North West Territory. Canadian, American, Australian and Russian scientists have been participating in this major project.

There have been recent discussions in the US, bringing together many of the world's research workers in physically based fire behaviour modelling. This should lead to international collaborative research to link the small-scale physical model and the larger scale meteorological model. A proposal is being drafted for a further EU project to develop this physically based modelling, and this would include US, Canadian and Australian partners. This is an exciting period in international collaboration, and should lead to a better understanding of the phenomenon of fire.

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Using What We Know

Mr Robert Conroy[1]

ABSTRACT

Fire management is a developing science which is not restricted solely to biodiversity issues, but importantly also extends to economic, geodiversity, cultural heritage, socio-political, legal and health and safety issues.

The effective management of fire in Australia involves the proper recognition of land management objectives as a framework in which the construction of a fire management policy and strategic planning framework is undertaken. It also involves the process of effectively monitoring and reviewing performance.

Constraints to effective fire management include limited knowledge of important processes such as the behaviour of fire in diverse landscapes and the impacts of fire regimes on heritage and natural resource values. Problems relating to the practical implementation of approved policies and strategies are also an issue.

Current management approaches rely on limited knowledge and factual data, cautious extrapolations and hypotheses; informed and expert opinions and anecdotes. Implementation depends on having access to appropriate information, receiving community understanding and support, weather conditions and resource availability. The manager's role is to integrate the above into a common sense approach for the area in question.

Significant improvements have been made over the last ten years in the development and implementation of appropriate fire management policies and strategies. The contribution of research findings, technological improvements, coronial inquiry findings and the trend to employ professional land managers have all contributed to these improvements. Some examples are provided from New South Wales which illustrate recent improvements and current approaches to policy development, strategic planning, research and operations.

1 INTRODUCTION

Fire management is an important but difficult component of a land manager's business. Inappropriate bushfire regimes have been recognised as a potential threatening process to the achievement of biodiversity conservation objectives (Woinarski and Recher, 1997; EPA, 1995; DEST, 1996; and Gill and Bradstock, 1995). Individual bushfires may also pose a major threat to human health and to local and regional economies, though these impacts are not as well documented. It is therefore important that we get fire management right particularly in areas where fire and land management objectives may sometimes be in apparent conflict, such as in urban-park interface areas and wilderness areas.

What we know about the role and management of fire in natural landscapes comes from a variety of sources. It comes from detailed research, survey and feedback from monitoring projects. This information is passed on by way of scientific papers, theses or best practice statements. It comes from the manager's own understanding of how fire behaves and how the landscape responds to fire impacts. More often than not the manager's knowledge base is personal to the manager and is not written down. Unfortunately when the manager moves on, so does the knowledge. Or more usually it comes from the community whether it be local Aboriginal communities, local rural fire members or just plain locals. While each of these sources is as important as the other, I concentrate in this paper on inputs from scientific research.

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This paper will briefly discuss the importance of research to fire management, it will also dwell briefly on what is known as the knowledge transfer problem, it will show where and how fire management research is inserted into the planning process and it will present some of the principles which have been developed for management of protected areas from the fire ecology research area.

Finally, some examples of how research findings are turned into management prescriptions for protected areas in a range of bioregions in New South Wales are presented in the Appendices.

2 THE IMPORTANCE OF RESEARCH FINDINGS TO FIRE MANAGEMENT

Land managers are required to comply with an ever increasing array of statutory requirements and state, national and international agreements. Examples include the recent introduction of biodiversity strategies, clean air strategies, threatened species recovery plans, forest agreements, indigenous land use agreements and ecologically sustainable development obligations. While all admirable initiatives, they place considerable constraints and particular requirements on the implementation of programs such as fire management, because of the lack of surety on impacts and the public debate over the benefits of such programs. This debate can often lead to legal challenges by third parties over the implementation of programs, public furore, coronial inquiries and political backlash.

Land managers have the problem of trying to coordinate fire management programs whilst also trying to achieve outcomes in other programs such as outdoor recreation, pest control, neighbour relations, natural resource (water, air) management, biodiversity and catchment management programs. Strategies have to be defendable, they have to be credible and they have to be well communicated and understood. The public needs to have confidence that the implementation of fire programs are in the public's interest.

Research, monitoring and survey can assist. Research into the effects of bushfire on our environment (ie natural, cultural and socio-economic) is a time consuming but important process. For example, there is a huge variety of plant and animal species within NSW, each with different ecological requirements. It is going to take a long time to accumulate the information necessary to be sure of the environmental impact of implementing a certain bushfire regime in any area, let alone incorporating research findings from other disciplines.

3 THE KNOWLEDGE TRANSFER PROBLEM

Taylor and Callahan (1978) felt that there was an inherent "information transfer failure" between researchers and bushfire managers. Land managers have a reputation for being either slow, reluctant or unable to incorporate research findings into fire management planning. This is despite the plethora of information readily available from both researchers which can be effectively utilised to develop appropriate policies and management procedures for managing the various risks associated with bushfires. Examples include Boughton (1970) – a survey of literature concerning the effects of fire on the forests of Australia; CSIRO (1989) - a publication of Australian fire research in progress; Gill et al (1994) - a bibliography of fire research papers from a variety of disciplines; Williams and Gill (1993) - a framework document to assess the impact of fire management practices on the natural heritage values of native forests in eastern NSW and the Australian Capital Territory; and Brown et al (1998) – a database on the effects of fire on the fauna in the Australian Alps National Parks. There are many other examples.

Other initiatives such as the development of FireNet (Green et al, 1993), an international network of people interested in fire management and research, and the Australasian Fire Authorities Council (AFAC) web site are examples of researchers extending their networks and sharing information.

Possible reasons for communication failure between researchers and managers might be attributed to the following:

3.1 Failure to Adequately Define Land Management Objectives

There are still a large number of areas in New South Wales for which management plans have not been formulated. These areas often rely on general statutory objectives rather than specific management objectives. This creates problems for both researchers and managers as they don't know what questions they are trying to answer for the area in question. This problem has been highlighted a number of times by Gill (1977) and Bradstock (1999) and others. Management research needs are difficult to define in an area where objectives and outcomes have not been explicitly stated.

3.2 Failure to Adequately Define Fire Management Objectives

Fire management objectives are difficult to describe when there is no land management framework in which to nest them. If there are no fire management objectives then the difficulties defined above (ie defining research needs) are further compounded.

3.3 Lack of Appropriate Skills in Managers

There still exists an inability in some areas for managers or even agencies to effectively communicate their research needs. It is also true that until recently land managers and fire authorities have not required tertiary qualifications for staff to occupy positions of influence. Liaison with tertiary institutions and research organisations has been haphazard and usually poorly resourced. For many land managers, applied research is unfamiliar and uncomfortable territory. The ability to convert knowledge into policy and procedure requires skills that are not always available to land management agencies and fire authorities alike. Those organisations who employ inhouse fire management specialists are better able to build linkages between field staff, managers and researchers and are better able to convert research findings into policy and procedure.

3.4 The Specificity of Research Findings

A large amount of the published material available to be converted to policy and procedures is temporally and spatially restricted. The extrapolation of material from one area to another is fraught with danger. Land managers are understandably reluctant to prescribe a policy rule which has its origins in narrowly defined methodologies. There is no certainty that a finding in one area can necessarily be translated to another. The inadequacy of information and knowledge on fire management impacts on invertebrates, lower plant species, scenic amenity, air emissions, impacts on cultural heritage and regional economic impacts; contributes to the manager's nervousness about implementing research findings from specific research studies. As elegantly described by T.H. Huxley "The great tragedy of science of course, is the slaying of a beautiful hypothesis by an ugly fact". Managers may relish the finding of such examples.

3.5 The Size of the Knowledge Gap

It is a fact that there are too many questions and not enough answers. The problem is so big and difficult to address that some managers are resigned to the fact that we will never know enough and may in fact give up on research ever finding "the golden bullet". It probably never will. Christensen (1998) however asserted that "We cannot do nothing until we know everything". It is easy however to see why some managers may get cynical.

3.6 Lack of a Common Language

This is an important issue. If managers and researchers are using language that can be interpreted differently by the other group then confusion and misinterpretation of results and needs will eventuate. For example the use of terms 'wildfire' and 'prescribed fire' are often open to ambiguous interpretation in some research publications. It is often assumed that when we mention wildfires we are referring to intense unpredictable events. This is not always the case. Similarly prescribed burns are not always low intensity broad area burns. The AFAC glossary of rural fire terminology (1996) is a useful tool that managers and researchers might use to aid in communication of research findings and research needs.

Similarly the use of scientific jargon in research reports, while necessary in terms of peer review, may not be easily interpreted by managers who are unfamiliar with such terms.

3.7 Implementation Problems

Managers may be reluctant to convert some research findings into policy because of the expectations and resources that the implementation of that finding may draw. The increasing development and use of GIS tools and decision support software and the implementation of new technology such as geographical positioning systems, airborne infra-red and satellite imaging are making this problem less of an issue. However it is nevertheless important to remember that many managers are not trained in the use of tools employed by researchers and often do not have access to the technology of training necssary to implement some research findings. Similarly while land managers might identify research needs, unless adequate resources or in-kind assistance is provided some research projec ts will never get off the ground.

3.8 Failure to Adequately Collaborate

Failure by both managers and researchers to collaborate will lead to lack of proper identification of what answers are required, lack of ownership and consequently poor communication of the research results and research needs at the end of the day. Many managers will admit that they have not properly identified research needs, and even if they had that they have not been passed on these needs to tertiary institutions. Many managers will also tell you that the first time that they knew that research work was being conducted in their patch was when they came across the paper in a scientific journal.

Managing the threats of bushfire regimes and of individual bushfires, requires active and conscious management of an integrated program of bushfire mitigation (including recovery), suppression and prevention activities. Such a program needs to be driven by policy and procedures which are developed from the best available information, developed from a mixture of research, survey and monitoring, local knowledge, intuition and national or international best practice strategies.

The Australian Fire Authorities Council (AFAC) published a position paper on fire management in March, 1996. The position paper advocates the importance of linking fire management activities with research. The paper states:

> "9. A national research effort be maintained in coordination with state organisations to investigate common fire management problems, including improvement of fire equipment and firefighting technology, knowledge of fire effects and behaviour, management and suppression of fires and the improvement of fire weather forecasting, sociological matters, and human behaviour before and during emergencies.
>
> 10. Each state should maintain a research effort to address its own particular needs and problems as determined by the characteristics of its vegetated ecosystems and climate and to improve the scientific basis for and effectiveness of fire management programs.
>
> 11. Land managers should develop and implement effective monitoring systems to measure the impacts of wildfires, prescribed fires and other fire management operations on the environment and to ensure that stated management objectives are being met."

The National Heathland Fire Behaviour Project and Project Vesta (research on high intensity fire behaviour in dry sclerophyll eucalypt forest) are two national projects supported by AFAC and are both good examples of collaboration between researchers, land managers and fire authorities.

In using what we know, it is important to identify where the incorporation of research findings and the identification of research needs fits in terms of the planning context. Appropriate planning structures give a focus to debate and are likely to lead to more informed choices. The following example is drawn from New South Wales National Parks and Wildlife Service.

4 PLANNING CONTEXT

A eight step planning process has been adopted for fire management planning in protected areas in New South Wales. This process identifies the important tasks involved in the development of bushfire management plans. The eight steps are:

4.1 Framing of Objectives

For the area concerned determining the reasons for reserve establishment, and the statutory objectives relating to the tenure of the land and any national or international agreements that may apply. This can be derived from a variety of Acts, Hansard, Register of the National Estate and from management plans and the regional nesting of the fire management plan within other planning instruments.

4.2 Compiling Knowledge

Research findings play an important role in this step. This step involves the review of current information relating to the natural and cultural heritage of the area, fire history, fire weather and assets at risk. In particular fire-sensitive species, communities and areas must be identified. Information and knowledge can be collated from a variety of sources including from specific resource surveys and from data and information held in local libraries, universities and colleges and government departments. Local community groups such as volunteer bush fire brigades, conservation groups, Aboriginal communities and historical societies can also contribute knowledge, information and data. The Bibliography of Fire Ecology in Australia (Gill et al, 1994) is a very useful reference for this purpose.

4.3 Developing Fire Management Principles

Gill (1975 and 1977) was one of the first to convert research findings into guiding principles for fire management plans - with the introduction of the concept of fire as an environmental variable, the concept of fire regimes and the categorisation of species responses to those regimes.

Contemporary ecological research in fire-prone has established some general principles about the fire regimes needed to avoid the extinction of species and to promote biodiversity. The principles adopted for fire management planning in New South Wales National Parks and Wildlife Service are:

Groups of plant and animal species respond similarly to fire according to characteristics of their life-history. Therefore, it is not necessary to individually specify fire regimes for the conservation of every species. Rather an overview is needed of the requirements for broad groups of species. Requirements for most plant species can be summarised on the basis of a small number of groups. Knowledge of requirements for groups of animals is less advanced.

Animals and plants are interrelated. Plants form an important component of habitat for animals. Fire management must consider this important interaction.

A diversity of fire regimes may be needed to maintain native biodiversity. This means that over time there is a place for fires of high, low and moderate intensity, frequency and size. Local extinctions are likely when fire regimes of relatively fixed intensity, frequency and extent occur.

For some groups of biota, thresholds separating desirable and undesirable fire regimes, for conservation, can be defined (eg Kendall’s (1993) ‘ecologically safe fire window’). Management should therefore be targeted towards desirable fire regimes using these thresholds as a guide. Management strategies therefore involve the manipulation of fire regimes.

Assessment of fire regimes through mapping of the locality and characteristics of all fires will be ongoing so that strategies (manipulation of fire regimes) can be regularly reviewed, refined and adjusted. Depending on the circumstances (a function of community type and prevailing fire regimes) there may be a role for both prescribed fire and / or fire-exclusion in parts of a given Reserve at different times in the future.

These principles are currently restricted to the fire ecology area. Similar principles are under development for other issues such as smoke emissions, regional economic impact, cultural heritage protection and fire suppression.

4.4 Preparing the Draft Plan

This involves the development of draft fire management objectives which are consistent with the general management objectives of the reserve and which accounts for the reserve being within the regional landscape. The draft plan contains a set of principles, policies, strategies and actions using a standardised fire management zoning approach. Performance indicators are also defined for the outcomes within the plan and these are then used to develop management information systems which can monitor and report on these indicators.

4.5 Assessing Impact

This step involves preparing an assessment of the likely impacts of implementing the Plan including socio-economic impacts, impacts on cultural heritage and impacts on natural heritage and resources.

4.6 Public Consultation

Exposure of the draft plan and the associated EIA for public comment and peer review is an important step in the process as it is an opportunity to elicit further information about the area concerned and to expose management intentions to public scrutiny. Comments received are reviewed by an expert panel. Amendments to the plan are incorporated as a result of the comments received. The summary of comments, revised draft plan and environmental assessment are then referred to a reviewing officer for approval and adoption.

4.7 Implementation

The implementation of the plan is subject to other land management priorities, resource availability, ephemeral statutory constraints such as threatened species and clean air legislation, community support and weather. The narrow window of opportunity to undertake prescribed burning has been well defined by Gill (1987).

4.8 Review

The incorporation of feedback loops and reviews of the plan so as to build in the results of future research, surveys and monitoring programmes and other contributions is a necessary step in any quality program. The NPWS is interested in achieving continuous improvement and of incorporating adaptive management principles into its planning processes.

5 EXAMPLES OF CONVERTING RESEARCH FINDINGS INTO MANAGEMENT PRESCRIPTIONS

The NSW National Parks and Wildlife Service is embarking on major fire planning exercise across the parks and reserves of New South Wales. This program will see the development of specific fire management objectives and strategies for over 220 areas using the above eight step planning process.

This represents a first attempt by the Service to adequately define fire management objectives and strategies for these areas and to expose the plans and their associated environmental impact assessment to public comment. It is also the Service’s first attempt to round up the current information on fire management impacts and apply some management rules for the protected areas we manage. Appendices 1, 2, 3 and 4 provide examples of the way in which the fire management principles mentioned above, and specific research finding on the area concerned are weaved into a set of management prescriptions for specific fire management zones within that area. The areas used as examples are Ben Halls Gap in the Upper Hunter region, Bouddi NP on the Central Coast and Goobang NP in the central west of New South Wales. Appendix 4 details the sort of considerations that land managers need to take into account when considering the impacts of fire management activities on Aboriginal sites. The impact of fire management on traditional use practices of Aboriginals in New South Wales has not yet been well addressed. Though like some of the issues, at least it has been recognised as a failing in the current approach and the gap is closing.

6 CONCLUSION

Bradstock (1999) pointed to a number of problems in closing the gap between researchers and managers and of incorporating science into management programs. They included unclear management objectives, inappropriate use or extension of concepts; assumptions about the possibility of controlling wildfires, failure to use knowledge and the lack of appropriate performance indicators. Many of these problems and others as mentioned herein still exist.

Nevertheless things have changed significantly over the last ten years and we are slowly learning to overcome these problems through the use of new and enhanced information technology; through the updating of fire management bibliographies and as a result of the increasing trend towards the appointment of professional land managers.

Managers could further assist by defining management objectives and listing and updating research needs both within management plans. These findings need to be discussed first hand with the most relevant tertiary institution. Resourcing research projects also needs to be considered either as direct funding or as provision of in-kind services such as access to files, access to remote areas, staff, accommodation and transport. Williams and Gill (1993) saw a need to assess the value of the concept of ‘experimental management’. This involves the landscape being treated as an unreplicated experiment where with good records and a simple monitoring scheme, some knowledge on fire impacts can be gained and opportunities to learn need not be wasted. Managers need to consider that there is merit in the gathering of information albeit from pseudo-scientific work.

Researchers could further assist by collobarating further with land managers and fire authorities and focusing their research projects so that they contribute to the achievement of management objectives. They could also assist by ensuring that research results are communicated by way of seminars to the land managers and fire authorities most affected. They could also assist by preparing plain english ‘management impact statements’ to accompany their research findings.

Land management authorities are moving away from the use of myth, intuition, anecdote and casual observation in the development of fire policy and are increasingly turning to fire management specialists and research results in the development of fire management principles.

A multi-disciplinary approach is essential. The development of a cooperative research centre which integrates and links research in the previously unfamiliar areas of social, economic and air quality research, together with the more traditional areas of fire management research such as fire ecology and fire behaviour research, is worthy of consideration.

In late August 1999, the Federal Minister for Industry, Science and Resources called for industry and researchers to develop new proposals for government funded research. A formal call for the establishment of cooperative research centres will occur this month (ie September, 1999). The closing date for applications is July, 2000. It may be time to develop strategic cooperative relationships in the area of fire management in order that competitive bid can be developed. Cooperative research centres are all about transferring knowledge and technology to industry to avoid the accumulation of orphan intellectual property that is often left languishing for someone to market it.

T.H Huxley[1] is quoted as saying - ‘*If a little knowledge is dangerous - where is the man who has so much as to be out of danger*?’ I wish I knew such a man (or woman) I would ask him/her how I can at reasonable cost and with some surety, minimise the risk of bushfire danger to life and property, while also preserving our wonderful natural and cultural heritage values in my area of responsibility.

It would appear that we are all in danger and will be for some time to come.

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[1] T.H. Huxley (1825-79) On Elementary Instructions in Physiology (1877).

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Fire Management Prescription Guidelines
Ben Halls Gap NP

Table 1: Fire regime guidelines for vegetation communities - Ben Halls Gap NP

Functional Community	Vegetation Community	Plant species decline possible if the following fire regime thresholds are exceeded	Regime
Rainforest	G - Cool Temperate Rainforest Sphagnum Moss Endangered Ecological Community	Any fire	A
Open Forest	A - Messmate / Mountain Gum Tall Open Forest B - Mountain Gum / Snowgum Tall Open Forest C - Messmate Tall Open Forest D - Silver-topped Stringybark / Mountain Gum Tall Open Forest E - Snowgum Open Forest	Two or more successive fires each less than 12 years apart No fire for more than 20 years Two or more successive fires with 100% canopy scorch	B
Riparian	F - White Banksia Tall Closed Shrubland	More than one fire every 100 years No fire for more than 200 years	C

Table 2: Fire management prescription guidelines for fauna - Ben Halls Gap NP

Species	Management prescription guidelines	Vegetation Community	Zone
Birds			
Avifauna	Apply vegetation management guidelines for vegetation types where species is known or predicted to occur. Maintain appropriate fire regimes for the purpose of creating a mosaic of communities with different ages and structures. Prevent a single wildfire event that will affect all known or potential habitats of the species.		
Pachycephala olivacea Olive Whistler	See Avifauna - general. Avoid burning which may remove shrubbery in cool temperate rainforest and adjacent lands.	Tall wet forest and rainforest, woodland, alpine heaths.	All
Ninox strenua Powerful Owl	See Avifauna - general. Avoid known nesting trees if trails construction is needed and allow a buffer area around known nesting areas to reduce disturbance by visitors using trails. Where nesting trees are located, prescribed burning to be conducted outside spring / summer breeding period.	More common in unlogged dry forest. Also found in moist forest.	
Mammals			
Great Pipistrelle Pipistrellus tasmaniensis	Avoid high intensity burns in known roosting areas and ensure no detrimental effects on the species habitat as a result of fire regimes. Avoid trail construction in known habitat areas.	Distribution uncertain. More common at cool elevations.	
Nyctophius timoriensis Greater Long-eared Bat	Apply vegetation management guidelines for vegetation types where species is known or predicted to occur. Maintain appropriate fire regimes for the purpose of creating a mosaic of communities with different ages and structures. Prevent a single wildfire event that will affect all known or potential habitats of the species.	Woodland. Roosts in tree hollows and under loose bark.	
Petaurus norfolcensis Squirrel Glider	Apply vegetation management guidelines for vegetation types where species is known or predicted to occur. Maintain appropriate fire regimes for the purpose of creating a mosaic of communities with different ages and structures. Prevent a single wildfire event that will affect all known or potential habitats of the species.	Wet and dry sclerophyll forests and woodlands. Nest in tree hollows.	All

Table 2 (Continued)

Species	*Management prescription guidelines*	*Vegetation Community*	*Zone*
Mammals			
***Dasyurus maculatus* Tiger Quoll**	Fire is a potential threat because the highest population densities occur in long un-burnt sites. Apply vegetation management guidelines for vegetation types where species is known or predicted to occur. Maintain appropriate fire regimes for the purpose of creating a mosaic of communities with different ages and structures. Prevent a single wildfire event that will affect all known or potential habitats of the species.	Recorded from a wide range of habitats, including rainforest, open forest, woodland, coastal heathland and inland riparian forest. Den sites have been recorded in caves, rock crevices and hollow logs.	
Koala *Phascolarctos cinereus*	Maintenance of a mosaic of fire frequencies in areas of Koala habitat will ensure the availability of suitable feed trees. Ensure trails do not dissect suitable Koala habitat. This species is believed to be unaffected by simplification of forest structure from frequent low-intensity prescribed burns as it relies solely on Eucalypts, however it is vulnerable to the effects of smoke generated from burning. Avoid high intensity burns.	Unlogged dry and moist forest.	

Table 3: Management guidelines for important plant species - Bouddi NP

Species	Conservation code	Habitat	Fire Prescription Guidelines
Alpinia arundelliana Zingiberaceae	Extension of southern limit	Confined to gully rainforest (1.6, 1.7).	No fire acceptable.
Banksia robur Proteaceae	Significant reduction in population	Confined to swamps or wet depressions usually on sand (4.2).	No fire acceptable.
Blechnum ambiguum Blechnaceae	Uncommon in the area	Confined to moist sheltered overhangs on Hawkesbury Sandstone in open forest (1.7).	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart.
Cryptocarya rigida Lauraceae	Extension of southern limit	Species prefers moist hardwood forest and rainforest (1.7).	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart.
Eucalyptus robusta Myrtaceae	Indicator species	Confined to Cockle Bay NR and Daleys Pt Ridge (1.7, 4.2).	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart. No fire acceptable.
Howittia trilocularis Euphorbiaceae	Uncommon in the area	Occasionally found in moist open forest and open forest (1.7).	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart.
Lepidosperma quadrangulatum Cyperaceae	Rare	Empire Bay (4.2).	No fire acceptable.
Melaleuca biconvexa Myrtaceeae	Limited range and reduced population	Confined to Pomona Rd area (1.7).	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart.
Olearia nernstii Asteraceae	Extension of southern limit	Bouddi ridge in disturbed areas (1.7).	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart.
Pararchidendron pruinosum Fabaceae		Found in riparian and gully rainforest habitats (1.6).	No fire acceptable.
Parsonsia velutina Apocynaceae	Extension of southern limit	Confined to rainforest (1.6)	No fire acceptable.
Ripogonum fawcettianum Ripogonaceae		Confined to very moist forest or gully rainforest (1.7, 1.6)	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart. No fire acceptable.

Rulingia hermaniifolia Sterculiaceae	Uncommon in the area	Prefers Hawkesbury sandstone rocky outcrops in windswept locations.	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart.
Tetrastigma nitens Vitaceae	Extension of southern limit	Confined to gully rainforest and very moist forest. (1.7).	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart.
Tylophora barbata Asclepiadaceae	Uncommon in area	Adapted to very fine habitat attributes (1.7).	Decline expected if more than two fires in a row occur at less than intervals of 8 years apart. Decline expected if more than two fires in a row occur at intervals of more than 15 years apart.

Table 4: Management guidelines for animals - Bouddi NP

Species	Management prescription guidelines
Amphibians	
Pseudophryne australis	Apply vegetation management guidelines for vegetation types where species are known or predicted to occur. Impact of timing unknown. Low intensity burn preferable.
Birds	
Avifauna - general	Apply vegetation management guidelines for vegetation types where species are known or predicted to occur. Maintain appropriate fire regimes for the purpose of creating a mosaic of communities with different ages and structures. Prevent a single wildfire event which will affect all known or potential habitats of the species.
Calyptorhynchus lathami	See Avifauna - general. Apply vegetation management guidelines for vegetation types containing *Allocasuarina* where species is known or predicted to occur.
Ninox strenua *Tyto novaehollandiae* *Tyto tenebricosa*	See Avifauna general. Prescribed burning to be conducted outside spring / summer breeding period where nesting trees are located. Low intensity burn recommended.
Pandion haliaetus	See Avifauna - general. Nesting trees (usually dead) may be affected by fires, need to maintain fuel reduced areas at the base of nesting trees. Prescribed burning to be conducted outside spring / summer breeding period where nesting trees are located. Low intensity burn recommended.
Xanthomyza phrygia	See Avifauna - general. Prescribed burning to be conducted after *Eucalyptus robusta* flowering.

Table 5: Management guidelines for animals - Goobang NP

Common Name	**Species**	**Status TSC Act *Occurrence***	**Preferred Habitats**	**Potential Fire Effects (Ayers et al (1996), Bradstock, R.A., & Date, E. pers.comm. & author's opinion)**
Mammals (cont.)				
Koala	*Phascolarctos cinereus*	Vulnerable *Resident*	Open forest and woodland containing food trees on higher nutrient status soils.	Removal of feed species especially in box woodlands and riparian red gum communities.
Squirrel Glider	*Petaurus norfolcensis*	Vulnerable *Predicted*	Open forests and woodlands.	Long absence of fire may cause a lack of nesting hollow regeneration.
Goobang Mouse	*Pseudomys* sp. aff. *novaehollandiae*	Possible new species. *Resident*	Rocky heath areas.	Not known. Studies on New Holland Mouse have found frequent fires reduce cover and feed availability while a long absence of fire results in cover becoming too dense and feed species declining. It is possible that the fire threats to this species may be similar.
Brush-tailed Rock Wallaby	*Petrogale penicillata*	Vulnerable *Predicted Resident*	Cliff areas containing caves, cracks and rock piles and which receive direct sunlight for much of the day and are in close proximity to open forests with grassy understoreys.	Frequent fire in feeding areas may reduce grass and herb availability.
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	Vulnerable *Resident*	Open Woodlands.	Long absence of fire may cause a decline in roosting hollow regeneration.
Little Pied Bat	*Chalinolobus picatus*	Vulnerable *Predicted Resident*	Open Semi- Arid Woodlands.	Long absence of fire may cause a lack of nesting hollow regeneration.
Greater Long-eared Bat	*Nyctophilus timoriensis*	Vulnerable *Resident*	Open Woodlands.	Long absence of fire may cause a lack of nesting hollow regeneration.
Birds				
Square-tailed Kite	*Lophoictinia isura*	Vulnerable *Predicted Resident*	Open Forests, Woodlands & Heathlands.	Frequent fires can directly reduce prey numbers. Frequent low intensity burns may reduce habitat quality of prey species.
Black-breasted Buzzard	*Hamirostra melanosternum*	Vulnerable *Predicted Infrequent Visitor*	Open Woodlands with grassy understorey.	Frequent fires can directly reduce prey numbers. Frequent low intensity burns may reduce habitat quality of prey species.
Grey Falcon	*Falco hypoleucos*	Vulnerable *Predicted Resident*	Open drier vegetation types such as Acacia Shrubland and Spinifex Grasslands.	Frequent fires can directly reduce prey numbers. Frequent low intensity burns may reduce habitat quality of prey species.
Bush Thick-knee (Curlew)	*Burhinus magnirostris*	Endangered *Predicted Resident*	Open Woodlands with grassy understorey.	Frequent fire temporarily reduces density of food items and greatly reduces density of fallen timber (prime shelter).
Glossy Black Cockatoo	*Calyptorhynchus lathami*	Vulnerable *Resident*	Open Woodlands containing Allocasuarina diminuta in hilly rocky ridge country and A. luehmannii on western foothills. Require hollows in mature trees on flat ground.	Frequent fire in vegetation communities containing Allocasuarina species can remove foraging habitat. Long absence of fire in foothills woodlands / forests may cause a reduce regeneration of nest hollows.

Table 5: (Continued)

Common Name	Species	Status TSC Act *Occurrence*	Preferred Habitats	Potential Fire Effects (Ayers et al (1996), Bradstock, R.A., & Date, E. pers.comm. & author's opinion)
Birds (continued)				
Pink Cockatoo	*Cacatua leadbeateri*	Vulnerable *Predicted Infrequent Visitor*	Open Semi Arid Woodlands containing cypress pine and she oaks. Require old growth mallee for nesting.	Frequent fire in habitat can reduce feed and nest site availability. Long absence of fire may reduce regeneration of nest hollows.
Purple Crowned Lorikeet	*Glossopsitta porphyrocephala*	Vulnerable *Predicted Infrequent Visitor*	Prefers mallee but may use flowering Open Woodlands / Forests.	Intense fires causing tree damage may reduce or interrupt flowering of some eucalypt species.
Superb Parrot	*Polytelis swainsonii*	Vulnerable *Predicted Resident*	Open Box and Red Gum Woodlands / Forests especially White Box.	Intense fires causing tree damage may further reduce feed supplied by these very limited vegetation communities. Long absence of fire may reduce regeneration of nest hollows.
Swift Parrot	*Lathamis discolor*	Vulnerable *Winter Resident*	Open Forests / Woodlands provide winter feeding areas.	Intense fires causing tree damage may reduce or interrupt winter flowering of some eucalypt species.
Turquoise Parrot	*Neophema pulchella*	Vulnerable *Resident*	Open Woodlands adjacent to grasslands, heaths or clearings.	Frequent fires may reduce number of low nesting hollows such as logs, stumps and posts preferred by this species.
Powerful Owl	*Ninox strenua*	Vulnerable *Predicted Visitor*	Old growth Open Forest / Woodlands.	Frequent fires can directly reduce prey numbers. Frequent low intensity burns may reduce habitat quality of prey species.
Masked Owl	*Tyto novaehollandiae*	Vulnerable *Predicted Visitor*	Open Forests / Woodlands adjacent to grasslands, heaths or clearings.	Frequent fires can directly reduce prey numbers. Frequent low intensity burns may reduce habitat quality of prey species. Long absence of fire may reduce habitat quality for ground dwelling prey species and regeneration of hollow roosting sites for arboreal prey species.
Gilbert's Whistler	*Pachycephala inornata*	Vulnerable *Predicted Resident*	Open Ironbark / Cypress Pine Woodlands with shrubby understories.	Frequent fire may remove feed and shelter shrubs from understorey. Long absence of fire could also result in declines in feed and shelter shrubs. Frequent fire may also reduce invertebrate prey diversity and densities.
Regent Honeyeater	*Xanthomyza phrygia*	Endangered *Winter Resident*	Open Box and Ironbark Woodlands.	Intense fires may cause tree damage interrupting winter flowering of feed species and reducing bark availability for nesting. Frequent fires may reduce invertebrate prey diversity and density.
Painted Honeyeater	*Grantiella picta*	Vulnerable *Predicted Visitor*	Open Woodlands / Forests with heavy mistletoe.	Frequent fire removing mistletoe from canopies.
Pied Honeyeater	*Certhionyx variegatus*	Vulnerable *Predicted Visitor*	Open Woodlands on western foothills during flowering of shrubs.	Frequent fire may remove feed shrub species. Long absence of fire may cause declines in feed shrub species.

Table 6: Fire Management Guidelines (General) - Goobang NP

Area/resource	Operational guidelines
Vegetation communities where the time since last fire is below the lower level threshold	• minimise burn area, if possible.
Vegetation communities where the time since last fire is approaching or exceeding the higher level threshold	• maximise burn area within the fire management area with consideration to: – management of heathland includes maintaining appropriate fire regimes for the purpose of creating a mosaic of communities with different ages and structures; – the fire will be contained within fire management area boundaries; and – after consultation with neighbours and the Executive Committee of the appropriate Bush Fire Management Committees.
Threatened species of flora	• brief all personnel involved in control line construction on the location of sites and required control line route. • exclude sites from burn area if the fire-free interval has not reached the lower level threshold.
Threatened species of fauna	• conduct baiting programs after fire events to reduce the impact by predators on native populations.
Aboriginal site locations	• brief all personnel involved in control line construction on the location of sites and required control line route.
Earth moving machinery	• where possible restrict use to existing or previous trail or control line routes. • exclude machinery from slopes greater than 30%. • close and rehabilitate all new tracks constructed for emergency operations immediately after the incident. • incorporate remedial works for erosion control. • brief all personnel involved in control line construction / maintenance on the location of aboriginal sites.
Fire fighting chemicals	• wetting & foaming agents permitted for use in wildfire control. • exclude the use of wetting & foaming agents in environmentally sensitive areas (eg. 20m of creek lines). • the use of retardants will be avoided where reasonable alternatives are available and will follow procedures in *Fire Management Manual*. • salt water permitted for water bombing operations in all areas.
Smoke and light management	• prescribed burning is to be conducted where possible by best practice guidelines described by Conroy, 02/96.
Visitor safety	• the park may be closed to the public when it is considered necessary due to conditions which create an extreme fire danger or during fire fighting operations.

Table 7: Impact of Fire Types and Suppression Activities on Aboriginal Heritage

Site Type	High Intensity Fire	Low Intensity Fire	Slashing	Dozer Lines	Grazing
Open Site	• post fire soil erosion may cause artefact movement and damage archaeological deposits.	• probably low impact except if damaged by vehicle traffic.	• moderate to high impact if driven over.	High impact	• low impact if stock pressure is limited and erosion prevented.
Scarred Tree	• depending on intensity may cause tree death, erode tree stability or damage scar. • fire may also lead to decline in tree health and promote rot. • may destroy dead trees.	• low impact if site is protected from fire using buffer zone. • if not protected, may undermine tree health. • may destroy dead trees. • high impact if struck by vehicles.	• high impact if struck by slasher or vehicle.	• as above	• low impact but may need to prevent stock rubbing or chewing tree.
Carved Tree	• as above.	• as above.	• as above.	• as above	• as above.
Engraving	• high intensity fire may cause spalling of sandstone and damage engraving. • post-fire soil erosion may cause build up of soil on site which can lead to chemical weathering.	• low impact if protected using buffer zone. • high impact if driven over.	• moderate to high impact if driven over.	• as above	• high impact if hard hooved stock trample site.
Axe Grinding Groove	• high intensity fire may cause spalling of sandstone and damage grooves. • post-fire soil erosion may cause build up of soil on site which can lead to chemical weathering.	• as above.	• as above.	• as above	• as above.
Rock Art Site	• high intensity burn may damage shelter surface and cause loss of art. • smoke blackening will obscure or damage art motifs. • removal of protective vegetation at shelter entrance may promote later weathering.	• low impact, especially if protected by buffer zone. • if not protected may still lead to smoke damage and removal of protective vegetation.	• low to no impact if protective vegetation is not damaged. • high impact if vehicle enters shelter.	• as above	• high if stock enter shelter and rub art or erode deposit. • otherwise low impact.
Shelter with Deposit	• post fire-soil erosion may lead to artefact movement and damage to archaeological deposits.	• low impact.	• as above.	• as above	• as above.
Mission	• fire may destroy or damage historic structures and features such as fencing.	• potential high impact as structures and features may still be damaged or destroyed.	• high impact struck by slasher or vehicle. • moderate if driven over.	• as above	• potentially low except where stock cause erosion or damage structures.
Bora Ring	• may remove protective vegetation and promote post-fire soil erosion.	• low impact. • high impact if driven over.	• potentially high impact if driven over. • may be offensive to local people.	High impact	• high impact if stock pressure is high and causes erosion.

Table 7: (Continued)

Site Type	High Intensity Fire	Low Intensity Fire	Slashing/Mowing	Dozer Lines	Grazing
Story Place / Landscape Feature	• may damage the ability of culturally significant vegetation (eg: food and medicine plants) to propogate. • may cause post-fire erosion and landform modification.	• low impact if erosion is unlikely or vegetation modification slight. • low impact if food or medicine plants are not prevented from propogating. • high impact if there are cultural reasons for protecting site from fire. • potential high impact if driven over.	• potentially low but would need to be discussed with local people.	High impact	• potentially low but may be objected to on cultural grounds. • high impact if causes erosion or alter vegetation (eg: damage food plants).
Midden	• may remove protective vegetation and promote post-fire erosion.	• low impact if protected with buffer. • low impact generally if post-fire soil erosion is not caused. • high impact if driven over.	• moderate to high impact if driven over.	High impact	• potentially low unless stock cause erosion. • may be objected to on cultural grounds.
Burial	• may promote post-fire erosion which can expose remains, especially in sandy soils.	• may be offensive to local people. • high impact if it damages grave features such as headstones. • high impact if driven over. • low impact if doesn't cause post-fire erosion or damage headstones or other grave features.	• possible high impact from vehicles where burial is exposed or close to surface. • may be offensive to local people. • may damage grave features.	High impact	• would be objected to for cultural reasons. • may cause erosion.
Quarry	• low impact except where post-fire erosion causes artefact movement or damages archaeological deposits.	• low impact except if driven over.	• high impact if driven over.	High impact	• potentially low unless stock cause soil erosion.
Stone Arrangement	• may cause spalling of stones in an arrangement. • post fire soil erosion may lea d to displacement of stones.	• low impact if post-fire erosion is not promoted. • high impact if driven over.	• high impact if driven over.	High impact	• high impact if stock move stones, cause erosion or alter vegetation (eg: damage food plants).

Public Awareness of Fire and Natural Resource Management

Dr Robert Sharrad[1]

In this paper I will concentrate on public awareness of fire and natural resource management - on peoples understanding of the ecological impacts of fire on native ecosystems and hence their ability to appreciate which are sensible land management options for the bush. However the matters discussed will also be relevant to the business of tackling public awareness of fire prevention, of fire suppression or of personal safety and fire. Now all of these are targeted by a great number of educational programs by Governments and agencies throughout Australia but you will have guessed that I am not convinced that the level of public knowledge about these matters is adequate. The communication of information about fire and natural resource management has not been as effective as we might like it to be. In this presentation I will suggest some reasons for this and some ways of making improvements.

It is important to note early that community ignorance about fire and the environment is probably part of a more general ignorance of the Australian environment and ecology. This ignorance sometimes leads to people making incorrect generalisations about fire and the bush and to press for inappropriate actions by land managers. This is most evident immediately after major fires where lives or property are threatened or lost. It is almost the rule that after such a fire there will be bitter condemnation of land management agencies and calls for more fuel-reduction burning and different approaches to fire prevention. This will be accompanied by a good deal of comment and advice about the role of fire in nature, past burning practices and so on. Discussion about these matters is quite crucial but is probably most likely to be productive well after the last wildfire and when those involved are well informed.

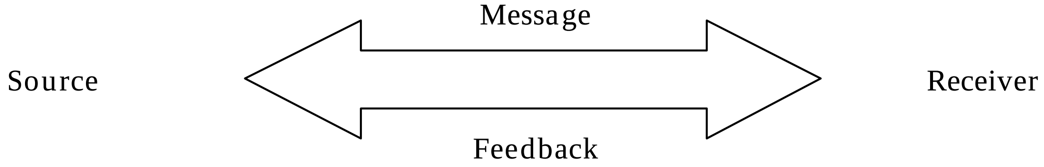
Helping to create a better informed public is an essential task for agencies involved in managing fire prone vegetation near human settlements. This involves skills in both communication and education.

1 MODELS OF COMMUNICATION AND EDUCATION

In the past some educators and other communicators saw communication as involving the simple transfer of information from a source through some suitable channel to a relatively passive receiver. The receiver in this rather primitive model of communication is sometimes seen as an empty vessel into which you pour facts, that are supposed to be assimilated.

Educators now agree that this one directional model is inadequate - perhaps we should observe here that some agency based programs still seem to rely on this approach (Cullen, 1998). A more appropriate model has the same components but also has feedback (Fazio and Gilbert, 1982). Some practitioners say that in what they call "persuasive communication" the component behaviour change should be added to the model - this behaviour change if observable is an important means of obtaining feedback (Braithwaite, 1990).

A Simple Communications Model



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The source of information (in this case usually a land management agency) must be seen to be credible and accurate for successful communication. The agencies involved here are quite highly esteemed so there shouldn't be a problem. The credibility of the land managers will of course be substantially reduced in the eyes of some people soon after a significant wildfire.

An important question should be asked here. Who in agencies should prepare the educational materials? Clearly they should be experienced and/or appropriately trained educators and communicators.

The message must be free of distortion, couched in appropriate jargon-free language and be pitched at an appropriate level. It must also be unambiguous! Do we always give the same message in a locality about control burns in parks for example?

In the case of fire and natural resources it is clear that information that applies in one part of Australia may not apply in other parts.

1.1 The Receivers Or Audience

Whether or not the message is successful depends on how well it matches the requirements of the various receivers, (the audience). The prior knowledge of the receivers, their attitudes, experiences, education, personalities, communication skills and so on, all help to determine the effectiveness of the message.

This view of receivers fits with what educators these days term a constructivist approach to teaching and learning in which they assume that people learn through an interaction between new information and prior knowledge. Educators generally believe that finding out what people already know is most important for the successful transmission of ideas.

It should also be noted that the audience is constantly changing through births, deaths and immigration so the job of informing the public never ends. There is also a constant movement of people between the urban and peri-urban areas.

It might be useful to make a few generalisations here about "the public" (ABS,1999):

- most Australians (84%) live in 1% of the continent;
- most live in cities, only 14% are categorised as rural;
- 23% of Australians were born overseas;
- 17% of Australians rate at the lowest level of literacy and can't understand the simplest written material.

The feedback part of the communications cycle is also very important and sometimes overlooked. Good communicators usually (always?) check to see that their message has been assimilated. Clearly this is quite difficult with some forms of communication but I suspect that much more should be done to see if in fact educational programs do hit the mark.

1.2 Factors that make it difficult to achieve satisfactory levels of knowledge about fire and natural resource management

The task of increasing public awareness in this area is quite difficult and several factors contribute to this, they include:

- the concentration of the population in cities - the urban/rural divide;
- a general lack of knowledge about the Australian environment;
- a lack of prior experience of fire by people living in peri-urban areas - partly as a result of good work by agencies in preventing fires;
- the fact that a large proportion of the population are from very different environments overseas;
- the tendency of the popular media to give more information about foreign environments than local ones;
- the centralisation of the media so that the natural history of some regions is rarely addressed;

- a decline in the teaching of environmental studies in some school systems;
- a reduction in field work in tertiary natural resource management courses;
- conflicting views (even among experts) about appropriate land management strategies such as control burning;
- the lack of research into fire ecology in some regional areas.

2 SOME SUGGESTIONS

- Land management agencies should accept that they need to inform the public about fire and natural resource management and that this will, in the long run, make their job an easier one. Sometimes they will need to prepare materials themselves but they should also work hard to see that such information is readily available to educators at all levels of the education system. They should help ensure that courses in schools and Universities on environmental matters are maintained and resourced.
- Fire information strategies should be developed by agencies in appropriately defined regions – this is of course being done in some areas (Seager, 1980) . What's true in one part of Australia isn't necessarily appropriate in others hence the need for carefully targeted local plans.
- Educational materials should be prepared and trialed by appropriately trained people in agencies or from outside.
- Feedback should be sought to gauge the effectiveness of communication.
- A variety of methods of communicating should be employed - via the internet, in Parks, through schools and so on.
- User friendly educational packages should be prepared by practising teachers for schools.
- The task is never ending and at times difficult but I think we can do better by adopting up to date methods of communication and education.

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