Refereed paper

Fire management in Australia: the lessons of 200 years.

Vic Jurskis[1] Bob Bridges[2] Paul de Mar[2] State Forests of NSW

[1,2]P.O. Box 273 Eden NSW 2551 Australia
[1] Email:vicj@sf.nsw.gov.au

Abstract

Ecologically sustainable forest management is government policy in Australia. Five key ESFM principles are: maintenance of all ecological communities and processes; public accountability; maintenance of ecosystem health and vitality by reducing threats from diseases, weeds and unnatural fire regimes; the precautionary principle; and adaptive management. Reduced occurrence of low intensity fire in recent decades is associated with fire control and forest health problems, indicating that forest fire management may need to further adapt if ESFM is to be achieved.

This paper reviews changes in policies and attitudes towards fire management in public forests since European settlement and current knowledge of the impact of various fire regimes on forest ecosystems. A widespread perception that prescribed burning is a serious environmental threat appears to be based on misunderstanding of the objectives and practice of prescribed burning, and extrapolation from observations of wildfires. Some changes to policy in New South Wales are suggested that may encourage precautionary and adaptive management, and ESFM.

Keywords: fire management, eucalypt forest, precautionary principle, dieback

Introduction

Australia’s National Forest Policy Statement (Commonwealth of Australia 1992) is a commitment to Ecologically Sustainable Forest Management (ESFM) including protection of the full range of forest ecosystems, maintenance of ecological processes, and protection against diseases, pests, fire and pathogens. Fire management programs may include prescribed burning to maintain biological diversity (Commonwealth of Australia 1992). Regional Forest Agreements (RFAs) set out five key ESFM principles including the precautionary principle. Despite formal commitments to these principles at all levels of government, the last decade has seen increasing public concern over both bushfire control (e.g. Hurditch and Hurditch 1994) and forest health (e.g. Jurskis and Turner 2002). We suggest some changes to fire management policies and practices that may better achieve RFA objectives and ESFM.

Fire regimes are usually described in terms of frequency, intensity and season (Catling 1991). Frequency has received much attention in recent ecological literature, however many discussions of frequent fire do not adequately address the issue of intensity and spatial variability. Different fire regimes can be ascribed to a point in a landscape, and the landscape as a whole, because of spatial variability. We discuss this issue and suggest that more emphasis on variability and intensity, rather than frequency, will improve understanding of fire ecology and management of fire regimes.

Historical Overview

Fire was commonplace in the Australian landscape prior to European settlement (e.g. AUSLIG 1990). Following European settlement, fire exclusion and suppression was a common practice in more highly developed areas, whilst deliberate burning was used in many outlying areas to reduce fire hazards or maintain grazing values. The frequency of intense fires in forests increased following European settlement. For example, two dendrochronological study sites in dry and wet eucalypt forests near Eden both showed an increased frequency of fire scarring since European settlement and similar studies in the Snowy Mountains region showed the same pattern (Richards *et al.* 1990). The increased frequency of intense fires was associated with a reduced occurrence of low intensity fires. Ward *et al.* (2001) demonstrated a decline from about three fires per decade under Aboriginal management to about one fire per decade under post European management of jarrah forests. During the same time, the average frequency of fires sufficiently intense to cause scarring on trees increased from one in 82 years to one in 13 years (Burrows *et al.* 1995). Thus, under a ‘fire exclusion’ policy, every fire in jarrah forest was sufficiently intense to cause some fire scarring of established trees.

Ward *et al.* (2001) reconstructed pre European fire histories by counting both annual rings and fire rings laid down by leaves of grasstrees. Other methods of investigation are unsuitable for studying low intensity fires. Sediment cores, dendrochronological disks, historical records and field observations are all less likely to record low intensity than high intensity fires. For example, McLoughlin (1998) examined the historical records of fires in the Sydney region between 1788 and 1845. There were 31 fires in the records, an average of only about one every two years. She concluded that most fires occurred in summer. An alternative conclusion could be that low intensity fires weren’t remarkable and therefore weren’t recorded.

Prior to European settlement and for more than a century afterwards, substantial areas were burnt by lightning fires every year. Little capacity was available to suppress fires outside populated areas, and these fires mostly burned until they were extinguished by weather or burnt into areas that were not flammable, such as recently burnt or moist areas. Nowadays more than 95% of lightning fires in New South Wales are extinguished before they reach 10 hectares. Those that escape control usually occur during dry seasons in advance of severe fire weather that promotes rapid spread and intense fire. Hence, the ‘natural’ component of modern fire regimes is dominated by fewer but larger and more intense, late spring or summer fires.

During the early 20th century, the development of forest management brought with it increasing efforts to exclude and suppress fires in forests (Shea *et al.* 1981). Extensive, and often disastrous, wildfires in all States around the middle of the century demonstrated the futility of these fire exclusion policies (Florence 1994). In the late 1950s and early 1960s, forest management agencies in Australia altered their fire management policies, abandoning fire exclusion in favour of the use of prescribed fire. They introduced extensive hazard reduction programs including aerial ignition (Shea *et al.* 1981).

The late 20th century saw increasing interest in natural and aesthetic values of forests, and extensive reservation of lands for conservation. During this time, environmental groups and conservation agencies raised objections to broadscale hazard reduction burning programs (Hurditch and Hurditch 1994) on the basis of perceived conflicts with biodiversity conservation (e.g. Bradstock *et al.* 1998). As a result, forest fire management policies changed again. In many cases, conservation agencies have opted for limited burning programs focussing on the interface between reserves and developed areas (e.g. Bradstock 2002).

An example of the impact of this change in policy was provided by reassessment of some flora survey plots in northern NSW during 2002. The initial survey in 1992 used 77, 0.1 hectare plots covering the full range of forest types and logging histories in State Forests' Urbenville Management Area (Binns 1995). In 1992, Binns (1995) classified ten plots as a group typified by grassy understories and a frequent fire regime. He suggested that some areas of dry forest should remain unburnt for longer periods of ten to fifteen years or more. When these formerly grassy and frequently burnt plots were reassessed in 2002 (State Forests unpublished data), they had all remained unburnt since the previous assessment. Four of the plots had developed denser shrub understories and were classified in different floristic groups compared to the original survey. Two of these plots were heavily infested by lantana. The eucalypts in the four shrubby plots were in moderate to severe decline.

Reduced occurrence of low intensity fire, development of dense shrub layers, and declining forest health are extensive in south eastern Australia (Gleadow and Ashton 1981, Rose 1997, Lunt 1998, Jurskis 2000, Jurskis and Turner 2002). The structural changes that are occurring in formerly grassy and open eucalypt forests are reducing the chance that low intensity fires will burn through these forests, making prescribed burning more difficult, and making wildfire control increasingly difficult and dangerous.

Ecological Implications of Prescribed Burning

Complexity and generalisations

Many ecologists have emphasised the complexity of designing appropriate fire regimes for conservation (e.g. Gill *et al.* 2002). Although there has been a large increase in ecological knowledge of fire regimes during recent decades (Keith *et al.* 2002, Whelan *et al.* 2002), the creation of new fire regimes is still bedeviled by a lack of knowledge (Gill *et al.* 2002). Whelan *et al.* (2002) suggested that there are many complex and unpredictable biotic responses to fire, making it difficult to arrive at useful generalisations. They suggested that a balance between useful generalisations, experimental precision and realism could best be achieved by researching ecological processes. We examine such a balance below, using some case studies.

Fire intervals and plant life cycles

A key generalization in the recent ecological literature (e.g. Keith *et al.* 2002) is that repeated fires at short intervals relative to the maturation period of obligate seeding plants will result in extinctions. In a long term burning experiment in blackbutt (*Eucalyptus pilularis*) forest at Bulls Ground, near Wauchope (northern NSW), small, obligate seeding shrub species were more abundant in plots that had been burnt ten times at about three yearly intervals than they were in plots that had remained unburnt for 30 years (Table 1, SFNSW Unpublished data). There are many reasons why this key generalisation may be unrealistic. Many 'sensitive' plants may not be killed by low or moderate intensity fires, and much of their seed supply may not be exhausted. Many may be concentrated in edaphic situations that are relatively little affected by lower intensity fires. Maturation times for 'sensitive' species may be shorter than expected, or they may be able to resprout from low intensity fires, and may have been mistakenly classified as obligate seeders following observations of wildfires.

Table 1. Number of plant species with contrasting regeneration strategies in frequently burnt and unburnt plots at Bulls Ground.

Regeneration Strategy	*Only in burnt plots*	*Only in unburnt plots*	*More frequent in burnt*	*More frequent in unburnt*
Obligate seeder	11	2	16	2
Resprouter	20	25	49	54
Total	31	27	65	56

Siddiqi *et al.* (1976) were cited as having documented local extinctions (Keith *et al.* 2002). However Siddiqi *et al.* (1976) reported that a wildfire eliminated some plants from a few survey plots covering very small areas, and the same species still occurred about 100 metres away in another (more sheltered) survey plot within the burnt area. Furthermore, the fire regimes they reported for the small survey plots, separated by this short distance, were quite different. Thus the statement that local extinctions had occurred appears unrealistic. Land managers would more likely conclude that the plots had all experienced the same fire regime, but that the more sheltered plot had not been burnt by every fire, and that the fire regime together with edaphic factors had influenced the distribution of plants in the landscape. The design of fire regimes based on life cycles may ignore the spatial variability of fires, especially low intensity fires, and place undue emphasis on fire frequency (e.g. Gill *et al.* 2002, Bradstock *et al.* 1995).

It is a common assumption that areas are burnt by prescribed fire burn in a fairly uniform and complete fashion (e.g. Catling 1991). This assumption may not be realistic in respect of much prescribed burning (Jurskis 2001). Hobbs and Atkins (1988) recorded high variability in temperatures within shrub layers and soils during prescribed burns. Only very intense fires in heavy fuels produced relatively uniform temperatures. They suggested that variability may be important in determining vegetation responses. Unpublished data from the Eden Burning Study (Binns and Bridges in press) show that there has been high spatial variability during the course of 5 prescribed burns over an 11 year period. Table 2 shows the frequency of small assessment plots according to the number of times burnt during the 5 prescribed burns.

Table 2. Frequency of assessment plots according to no. times burnt, Eden Burning Study.

No. of times burnt	***0***	***1***	***2***	***3***	***4***	***5***
Frequency of plots %	24	38	30	6	1	0

Much of the evidence for localised extinctions by fire appears to come from anecdotes and retrospective studies of wildfires. Gill and Bradstock (1995) listed 19 plants from 11 citations to support the proposition that many plant species have been locally extinguished by too-frequent fires. However no details were given of the frequency or intensity of these fires, nor whether they were prescribed fires or wildfires. One of the cited reports referred to eucalypt crown fires (Ashton 1981). Another of the cited studies referred to a “fierce fire” that burnt “virtually every plant in the area” (Siddiqi *et al.* 1976). We suggest that generalisations about extinctions caused by frequent fire are inappropriate without some consideration of the intensity and homogeneity of the fires, and that these aspects of fires may have been equally or more important than their frequency in producing the reported extinctions.

It is very difficult to design retrospective studies of fire regimes that can lead to robust conclusions. For example, Cary and Morrison (1995) compared vegetation between plots with a “wide variety of” fire histories including both wildfires and prescribed fires. They restricted their sampling to plots that had an "understorey structure consistent with the recorded fire history, and understorey apparently completely burnt by at least the most recent fires". The assumption was that all fires completely and uniformly burn understoreys. Fires that did not conform with the assumption were excluded from sampling. Therefore the generalisations arising from this study are unlikely to hold true for anything other than very uniform high intensity fires.

Biodiversity or biomass?

Ecological experiments target single or few species because it is impractical to measure total biodiversity. Where there are greater numbers or richness of the target group it is assumed that there is more biodiversity. Keith and Henderson (2002) proposed diversity of woody shrubs as a measure of biodiversity. However, the richness of all vascular plant species in the forest would be a more robust measure of biodiversity and may lead to different conclusions than a focus on shrubs. For example, in the Bulls Ground study, overall understorey species richness was higher in the frequently burnt plots than in the unburnt plots (Table 1), whereas there were more woody understorey species in the unburnt plots (State Forests unpublished data). York (1999a) found 15 litter dwelling invertebrate taxa in the unburnt plots compared to11 in the burnt plots, whereas York (2000) found 21 ant species in burnt plots compared to 17 in unburnt plots. Thus different conclusions may arise from consideration of the two different invertebrate samples**.** Catling (1991) suggested that a low intensity fire regime would advantage some small ground dwelling mammals and disadvantage others that are associated with complex habitat structure. Whilst shrubs and litter dwelling invertebrates may increase as a result of fire exclusion, other groups such as herbs (Lunt 1997), ants (York 2000) and some small mammals (Christensen 1998) may decline. Conclusions about impacts on biodiversity may depend on the groups that are targeted.

To evaluate the consequences for biodiversity, of low intensity fire regimes, it would be necessary to assess the relative rarity and robustness of populations and ecosystems that are either advantaged or disadvantaged by burning. Low intensity burning may favour relatively rare and vulnerable ecosystems and populations that make up a small proportion of total biodiversity, however these may constitute the highest risk of loss. For example, Lunt (1997) found that large populations of a number of plant species including a vulnerable orchid (*Diuris punctata*) were almost entirely restricted to small, frequently burnt railway easements on the Victorian Gippsland plain. Jurskis and Turner (2002) stated that 'bellbird dieback' of eucalypts on private lands in the Bega Valley is particularly associated with remnants of grassy forest types that have been largely cleared for agriculture.

Woody shrubs, litter and litter dwelling invertebrates may be increasing in the landscape (see above). Fire regimes that favour these components of biodiversity may not contribute to biodiversity conservation. For example, none of the shrubs considered by Keith and Henderson (2002) to be contributing to biodiversity in New South Wales' northern tablelands eucalypt forests were rare, therefore enhancing the shrub populations would be unlikely to support their stated objective "to minimize the risk of losing biodiversity from a management area". We suggest that biodiversity conservation would best be served by using more extensive low intensity fire to maintain or enhance the extent and health of ecosystems that have been most depleted since European settlement.

Off site impacts of fire regimes

Catling's (1991) theoretical analysis of contrasting fire regimes didn't consider impacts such as water pollution and siltation that may affect off site biodiversity. These have received little attention in fire ecology compared to their prominence in other aspects of land management. Good (1981) cited a study showing a thousandfold increase in soil erosion over more than a year as a result of wildfire. Birk and Bridges (1989) found that five times more fine fuels remained unburnt by prescribed fires in a blackbutt forest compared to a wildfire. Thus there was much less protection for the soil following wildfire. It is likely that a low intensity fire regime will generate less soil erosion, siltation and water pollution than a high intensity regime.

Stochastics, mosaics and pre-European fire regimes

Gill *et al.* (2002) recognised reintroduction of Aboriginal burning regimes as an option for biodiversity conservation but favoured the design of new fire regimes to suit target species. Keith *et al.* (2002) said that it may be difficult to determine precisely the Aboriginal fire regimes. They advocated the use of models that incorporate stochasticity, citing a report that a planned mosaic burning program failed to enhance ground parrot (*Pezoporus wallicus*) populations because it failed to anticipate stochastic fire events (Bradstock *et al.* 1995). Wardell-Johnston and Horwitz (2000) said that Aboriginal people probably used edaphic controls in skillful fire management over millennia. These contributions indicate a general view in the ecological literature that pre-European fire regimes may have been ecologically appropriate but are either unknown or impossible to emulate, and that the design of new fire regimes must incorporate stochasticity.

We suggest that edaphic controls have applied to the spread of fire throughout pre-Aboriginal, pre-European and contemporary periods. Ecosystems adapted to high intensity fire regimes are those adapted to edaphic situations that are not conducive to fire except under severe conditions. Examples are wet sclerophyll forests, rainforests and swamps. The study of Siddiqi *et al.* (1976) provided an example of edaphic control of fire regimes. Their site that had a longer time since fire was on a sheltered south easterly aspect and downslope from the other sites. Edaphic controls are reinforced by low intensity fire regimes in the landscape and they are weakened by high intensity fire regimes in the landscape. Low intensity regimes maintain dry, open, grassy conditions that allow fires to spread under mild conditions until they reach sheltered areas that are too cool, still and moist to burn in the mild conditions. Fire exclusion and / or intense fires cause shrubby vegetation with heavy, elevated fuel loads to develop in less sheltered situations, promoting rapid fire spread and high flames during moderate to severe conditions, and allowing fires to penetrate and burn through more sheltered positions.

Aboriginal burning regimes incorporated more low intensity fire than early European fire regimes (see historical overview above). The mid 20th century saw a shift back towards low intensity regimes. The concept of precisely defining low intensity fire regimes (Keith *et al.* 2002) with their inherent spatial variability is nonsensical. Stochasticity and high intensity fires are a fact of life, however it should be recognised that reduced occurrence of low intensity fire in recent decades has weakened edaphic controls and resulted in more extensive high intensity fires. Edaphic control of fire regimes is well recognised (e.g. Gill and Bradstock 1995, Woinarski 1999, Wardell-Johnston and Horwitz 2000), but there appears to be less recognition that this control is weakened by high intensity fire regimes. For example, Smith (1987) recommended fire exclusion to protect rare birds that had survived wildfires through edaphic protection. Gill and Bradstock (1995) emphasised the risk of short interval fires rather than weakened edaphic protection. The “mosaic paradigm” denounced by Bradstock *et al.* (1995) results from a lack of appreciation that edaphic protection was weakened and spatial variability was reduced when the occurrence of low intensity fire was diminished.

There have been many reports of local extinctions resulting from high intensity fire regimes (e.g. Smith 1987, Gill and Bradstock 1995, Woinarski 1999), but there is little or no evidence of species being depleted by a lack of high intensity fire. We suggest that a low intensity fire regime will maximise edaphic control and spatial variability in fire regimes in the landscape. Stochasticity will apply, particularly in edaphically ‘sheltered’ positions where infrequent fires will occur. Using low intensity prescribed fires to create natural, landscape scale fire mosaics is preferable to applying artificial rotational block burning strategies. There is less risk that wildfires occurring in addition to low intensity burning will disrupt populations of fire sensitive species.

Fire regimes and forest health

An extensive informal survey of forest health in New South Wales (State Forests unpublished data) recently indicated that about a quarter of a million hectares of coastal forests may be affected by eucalypt dieback. The dieback is associated with reduced occurrence of low intensity fires (Jurskis and Turner 2002). There is usually increased shrub development and often weed and bellbird invasion. Tuart (*Eucalyptus gomphocephala*) decline in Western Australia, and dieback associated with heavy koala (*Phascolarctos cinereus*) browsing in Victoria, have received extensive publicity, and fire exclusion has also been implicated in these problems (Anon. 2002a, Jurskis 2002). Lunt (1998) documented eucalypt decline in Victorian coastal woodlands with long term fire exclusion. Weed invasion and eucalypt decline with fire exclusion have also been reported by Gleadow and Ashton (1981), Smith and Smith (1990), and Rose (1997).

Prescribed burning has been reported to reduce topsoil nitrogen and moisture levels, rates of nitrogen cycling, forest floor litter and organic matter, and also to increase available phosphorous and ground level solar radiation (Raison *et al.* 1993, York 1999b, Guinto *et al.* 2001). Jurskis and Turner (2002) suggested that these results, viewed from an alternative perspective, indicate that fire exclusion can promote eutrophication, nutrient imbalances, unnaturally shrubby, and often weed infested understoreys and impaired eucalypt health, resulting in dieback. Granger *et al.* (1994) found abnormally high nitrogen levels and nitrophilous weed invasion in declining eucalypt stands. They noted that these observations were consistent with observations of nitrogen saturation in European ecosystems. White (1993) argued that all outbreaks of folivorous pests are a response to increased nitrogen availability.

High intensity fires can cause substantial increases in soil nitrogen and also stimulate prolific germination of nitrogen fixing trees and shrubs (Humphreys and Craig 1981). Birk and Bridges (1989) found that a wildfire in blackbutt forest promoted rapid understorey development, producing more than double the prefire weight of understorey fuel (up to 0.9 metres above the ground) within 18 months of the fire. Litter accumulation and cycling were altered by the wildfire, indicating that high intensity fires alter ecosystem function (Birk and Bridges 1989). Thus high intensity fire may reinforce changes in ecosystem processes brought on by fire exclusion and intensify eucalypt dieback.

Fire control implications of fire regimes

Bradstock *et al.* (1998) suggested that hazard reduction burning would be ineffective in wildfire control unless large areas were burnt, and that this widespread burning would likely extinguish some plant species. This suggestion was based on unrealistic assumptions about the objectives, practice and impacts of prescribed burning (Jurskis 2001). It has been suggested (e.g. Good 1981) that prescribed burning may be of little benefit in fire control because fuel weights quickly recover to pre fire levels. In news media, it is often reported that prior hazard reduction burning would not have assisted wildfire control because of extreme weather conditions.

These perceptions of ineffectiveness of hazard reduction burning are based on common misunderstandings. Hazard reduction burning is used to modify the quantity, arrangement and seasonal flammability of fuels. The objectives are to minimize the intensity, flame height and rate of spread of unplanned fires under any given seasonal and weather conditions. The objective is not to prevent fire propagation under any conditions as implied by Bradstock *et al.* (1998) and commentators in the news media. Frequently burnt areas are likely to have compact fuels close to the ground whereas long unburnt areas may develop vertically distributed fuels, including tall shrubs, that promote higher flames, rates of spread and crowning. Burnt areas may carry green ground fuels during summer compared to dry fuels in unburnt areas. Bark characteristics that promote high flames and spotting of fire in advance of fire fronts may take longer to recover after prescribed burning than fuel weights. Figure 1 illustrates differences in fuel characteristics between a frequently burnt and a long unburnt plot at Bulls Ground. The structural changes resulting from fire regimes that are considered by some authors to be ecologically appropriate (e.g. Catling 1991, Keith and Henderson 2002), provide obvious difficulties for fire control.

Figure 1. Frequently burnt (left) and unburnt (right) plots at Bulls Ground, showing different fuel characteristics resulting from different treatments.

The perceived conflict between human protection and biodiversity conservation has fostered a policy of restricting hazard reduction burning in reserves, mostly to buffers around developed areas (Bradstock 2002). These buffers feature in Bushfire Risk Management Plans prepared under NSW legislation. Good (1981) discussed the concept of hazard reduced buffers in relation to wilderness areas, and noted that it would be impractical to maintain buffers wide enough to prevent spotting over under extreme conditions. Cheney (1981) stated that long distance spotting up to 30 km ahead of the main fire is a characteristic of high intensity eucalypt forest fires. Hurditch and Hurditch (1994) stated that lives were lost when a 1994

Sydney fire spotted 800 metres across a major watercourse. Buffers around human developments can contribute to wildfire control under moderately dangerous conditions but cannot substitute for broad area hazard reduction as a protection measure against severe fires.

Prescribed burning allows for safer and more effective fire control under any given conditions and therefore minimizes the likelihood or extent of active fire fronts when severe weather conditions occur. McCaw *et al.* (1996) provided an example of wildfire burning at reduced intensity, being easier to control and doing less damage in an area where hazard reduction burning had previously been done. A number of recent case studies in New South Wales indicated that hazard reduced areas provided substantial fire control benefits, even under extreme fire danger (Anon. 2002b).

Birk and Bridges (1989) found that fire exclusion promoted the development of tall woody shrubs and that wildfires also promoted woody shrubs. Thus the structural changes in fuels that are produced by fire exclusion may be compounded by wildfires, resulting in the increasing difficulties in fire control that have recently been apparent in the landscape. These processes help to explain the commonly reported incidents of intense wildfires occurring in areas that were previously burnt by wildfires in the very recent past. Such anecdotes have been used to support the proposition that hazard reduction burning is ineffective in assisting wildfire control, however this use ignores the different processes that follow low intensity burning as compared to wildfire.

Public Perceptions

Theoretical evaluations (e.g. Catling 1991, Bradstock *et al.* 1998) have encouraged a widespread perception that frequent and extensive prescribed burning is threatening biodiversity in Australia and having little impact on fire control (Jurskis 2001). State Forests has for many decades been the leading practitioner of prescribed burning in NSW. Over the ten year period from 93/94 to 02/03, prescribed burning was carried out on 728,487 hectares of State forest (Anon. 2002b). This represents an annual average of about 3% of State forest land. During the same period, prescribed burning was carried out on 205,272 hectares of National Park, or an annual average of about 0.4% of the National Parks estate (Anon. 2002c). The majority of prescribed burns in National Parks are for community protection and are located in areas where National Park boundaries are adjacent to urban or rural communities (Bradstock 2002), whereas prescribed fire is used more widely in State forests. However, except for community interface areas, the period between prescribed burns is generally at least 5 years. Thus prescribed fire use is neither frequent nor extensive.

Wildfire statistics show a very different pattern from prescribed burning. The State forest area burnt by wildfires during the period 93/94 to 02/03 (as at 10 Februrary 03) was approximately 701, 500 hectares – less than the State forest area treated by prescribed fire. During the same period, the area burnt by wildfires in National Parks was in excess of 2.5 million hectares, more than twelve times the area treated by prescribed fire. The majority of this area was burnt by large, uncontrolled, high intensity fires on a few extreme days. In view of these statistics, the perception that prescribed burning is a threat to biodiversity is surprising. Wildfire appears to pose a greater threat to both biodiversity and human life and property. On current trends, efforts expended in grappling with the complexity of designing ecologically appropriate fire regimes and investigating responses of indicator species (e.g. Gill *et al.* 2002) will have application to less than 10% of the fire regime in New South Wales' conservation reserves.

More than 90% of the regime will comprise unplanned, extensive, relatively uniform, high intensity fires that will cause much social and environmental damage.

Precautionary and adaptive management

We suggest that recent reductions in low intensity burning have led to increased occurrence of high intensity fires and that these changed fire regimes have altered ecosystem processes and promoted eucalypt dieback. This type of fire management is not in accord with ESFM principles outlined above. The precautionary principle has often been misinterpreted as a caution against taking action where there is risk, however it actually cautions against delaying action to prevent environmental degradation because there is uncertainty (Commonwealth of Australia 1992). The principle has been inappropriately invoked as a justification for excluding deliberate burning from forests (Christensen 1998) on the basis of potential risks to biodiversity (e.g. Keith and Henderson 2002). Application of the precautionary principal to fire management requires action to be taken against the increasing incidence and extent of high intensity fire and eucalypt decline in the landscape.

Adaptive management is not research. It takes advantage of the lessons of the past and takes necessary actions accordingly. We suggest that restoring a greater proportion of low intensity fire in the landscape would be a precautionary approach compared to current management. Low intensity burning should be carried out in dry eucalypt ecosystems, especially the grassy ecosystems that are depleted and declining in health (Jurskis and Turner 2002). Monitoring is an essential component of adaptive management.

Current policies and regulations in NSW exclude low intensity burning from much of the landscape including wilderness, oldgrowth, rare ecosystems, habitats of rare plants or animals, and drainage lines. (e.g. Anon.1999). They focus on individuals, target species and fire frequency. They don’t encourage assessments of the consequences of not burning. This policy environment reinforces the shift towards more widespread high intensity fire regimes. Precautionary fire management should be encouraged by:

- developing guidelines and prescriptions for landscapes, not individual plants and animals
- developing prescriptions to control the extent and spatial variability of fires by controlling fire behaviour, rather than prescribing artificial exclusion zones and fire intervals
- recognising that low intensity burning protects edaphic controls and sensitive species, so that perceived conflicts between human and environmental protection are largely unreal
- recognising increasingly extensive high intensity fire regimes and eucalypt decline as consequences of fire exclusion that must be considered in planning

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