FIRE MANAGEMENT ON NATURE CONSERVATION LANDS

PROCEEDINGS OF A NATIONAL WORKSHOP BUSSELTON WESTERN AUSTRALIA OCTOBER 1987

Edited by
N. Burrows
L. McCaw &
G. Friend

OCCASIONAL PAPER 1/89

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

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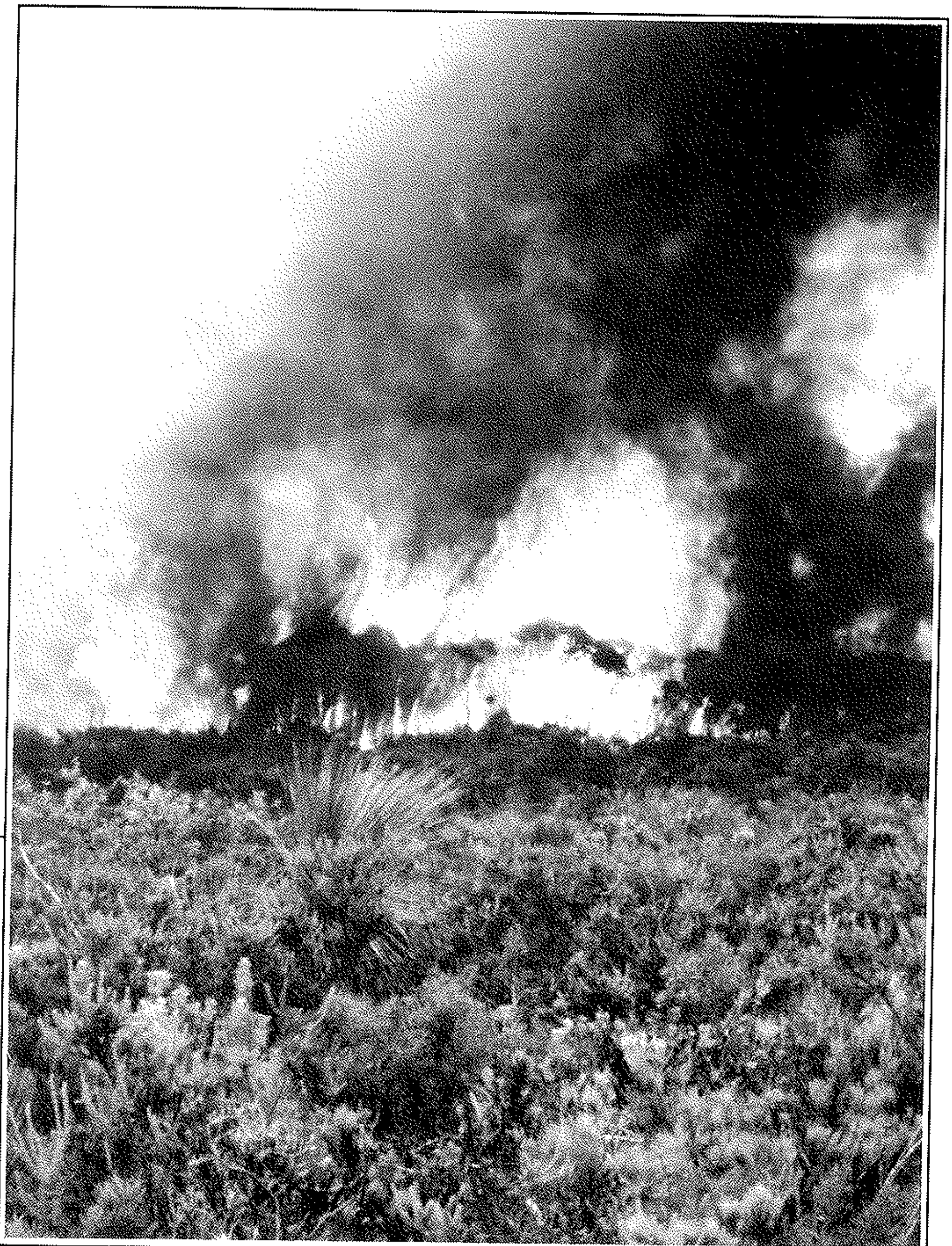

Cover Photo: Using prescribed fire to establish a fuel reduced buffer strip in low shrubland at Mt. Lesueur near Jurien, Western Australia.

Photo by L. McCaw

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FORWARD

Fire is an integral part of the Australian landscape, is an important enviromental factor and is probably the greatest single issue facing land managers today.

The Western Australian Department of Conservation and Land Management hosted a five day National Workshop on the theme "Fire Management On Conservation Lands".

The objective of this national workshop was to bring together policy makers, planners, managers, scientists and representatives from interested community-based groups to exchange ideas and to jointly tackle the complexities of planning for fire management on lands where the primary use is to protect conservation values. Such lands include National Parks, State Parks, Nature Reserves and some State Forests.

In particular, the Workshop organisers were looking for a conceptual planning framework to evolve. Such a framework could then be applied for planning fire management for a wide range of situations. Invited papers presented by experts from around Australia provided background material for the syndicate style exercises on selected case studies.

Papers were presented in six sessions over two days, each session concentrating on a theme relevant to the planning process. To ensure freedom of expression and to maximise diversity of perspectives, authors were not given binding titles, but were asked to address their theme as they saw fit. While there was a risk of some overlap, this was seen as a positive thing in that it indicated something of a "universal" approach to the planning process.

Day three of the workshop provided a break away from the auditorium by way of a field trip to inspect fire management activities in forests and coastal areas near Busselton.

Days four and five were dedicated to workshop sessions. The objective of the workshop sessions was for syndicates to develop a systematic procedure for preparing fire management plans for various conservation lands. Syndicates consisted of a range of people with various backgrounds and disciplines and each syndicate worked on actual case studies involving National Parks, Nature Reserves and State Forests in Western Australia.

This workshop was very much planning and management oriented.

There have been numerous past occasions where technical aspects of fire behaviour and fire ecology have been aired. On no other occasion has such a wide range of people, representing land management organisations, tertiary institutions and community-based conservation groups from across Australia, assembled together to tackle the complexities of planning for fire management on conservation lands. Papers presented in these proceedings have not been scientifically refereed in the traditional manner as many papers represent the philosophies, experiences and opinions of managers, planners, community groups and researchers.

We believe this workshop and these proceedings make a valuable contribution to fire management and to conservation in Australia.

ACKNOWLEDGEMENTS

The Workshop Organising Committee thank the following people who ensured the success of this workshop.

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Chris Haynes
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CONTENTS

FIRE PROTECTION PLANNING FOR PUBLIC FORESTED LAND IN VICTORIA TO INTEGRATE PROTECTION, MANAGEMENT AND CONSERVATION OBJECTIVES

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INTRODUCTION

The Department of Conservation, Forests and Lands (CFL) was established in 1983 and given the responsibility for managing all public land in Victoria - approximately 40 per cent of the State's land area. The Department incorporates all or part of several previous natural resource management agencies (the State Forests Department, Crown Lands and Survey, National Parks Service, Fisheries and Wildlife Division and Soil Conservation Authority) which for many years had operated independently. CFL has an integrated approach to the management of public land and resources and one of its legal responsibilities is to protect these lands and resources from wildfire.

This is a particularly important responsibility in Victoria where, because of geography, vegetation, climate and type and extent of settlement the State is prone to frequent economic and physical damage from wildfire in its public forest areas. According to Luke and McArthur (1978) "During the last 150 years probably as much as half of the economic damage caused by bushfires in Australia has occurred in Victoria though it occupies only about three per cent of the total land surface". Loss of life has also been a regular event (see Table 1).

Table 1
Loss Of Life In Victorian Bushfires

Year	Lives Lost	Year	Lives Lost
1918	-	1962	14
1926	60	1965	7
1932	20	1967	-
1939	71	1969	23
1944	49	1977	5
1952	SEVERAL	1978	3
1955	-	1980	-
1958	-	1983	47
1959	-	1985	5

Fire Protection Planning

The CFL fire protection planning process recognises three levels of planning: strategic, operation and emergency. At the strategic level a Regional Fire Protection Plan is prepared as a public document in accord with Statewide standards developed by the Chief Fire Officer. At the operational level a Regional Fire Protection works program is prepared internally and approved by the Regional Manager. The works program details all the works and activities needed to implement the strategies outlined in the Regional Fire Protection Plan. It is prepared annually and describes the works and activities proposed for the next three years. At the emergency level the Fire Control Plan is an internal, short term action plan prepared as required by the Regional Fire Controller. It outlines the suppression strategies and actions considered appropriate to control and extinguish the wildfire. Figure 1 shows the relationship between these levels of planning and a description of the components of each level.

Principles

This paper deals with the process of arriving at a Strategy Plan. It is based on the following principles.

1 The plan is regionally prepared - this is necessary to ensure that local peculiarities and requirements are incorporated and to form a regional commitment to the plan.

2 The plan is based on Statewide standards and format - this is required to make the document readily understood by all sections of the Department and Statewide outside interested parties eg Apiarists Association, Conservation Council Victoria, Fire Protection Committees.

3 The strategy is based on protection of a total forest system - sub-plans for individual reserves are developed from the plan for the total system. This ensures that all works are integrated to provide the greatest effect.

4 Account is taken of management and conservation objectives and the ecological role of fire - the various management and community objectives are integrated into the plan by ensuring input from specialist officers from relevant disciplines, the various functional divisions of the Department, local interest groups (including rural fire brigades, conservation and client groups) and the general public. Normally where fire protection objectives and conservation or management objectives clash acceptable compromise can be found, but if it cannot, modification of management objectives may be necessary.

5 Departmental strategy plans are integrated with neighbouring regions and with Municipal Fire Prevention Plans - a Departmental arrangement provides for integration with neighbouring regions whilst there is legislative provision for the Regional Fire Prevention Committees to integrate the plans with municipal plans for private land areas.

6 Four major fire protection objectives must be addressed - to protect life, property and other assets from wildfire; to protect areas with special natural

STRATEGIC LEVEL

REGIONAL FIRE PROTECTION PLAN (Public Consultation)

PREVENTION

- Regional statement of prevention objectives and strategies.

PRE-SUPPRESSION

- Regional statement of pre-suppression objectives and strategies.
- Map

SUPPRESSION

- Statement of Departmental Fire Suppression policy.

OPERATIONAL LEVEL

REGIONAL FIRE PROTECTION WORKS PROGRAM

PREVENTION

- Annual schedule of prevention activities.
- Annual budget allocation.

PRE-SUPPRESSION

- Annual schedule of pre-suppression activities (including annual updating of suppression documents).
- Three-year schedule of pre-suppression works.
- Map
- Annual budget allocation.

EMERGENCY LEVEL

FIRE SUPPRESSION OPERATIONS

SUPPRESSION

- Fire Control Plan prepared as required following detection of a wildfire.

FIGURE 1
Fire Protection Planning Concept

and cultural values from wildfire; to restrict the spread and reduce the intensity of wildfire; and to reduce the incidence of wildfire.

Plan Structure

A series of data maps is developed for each region or forest system, usually at a scale of 1:100 000, to provide the basis for subsequent decisions on fire protection strategy. The data maps are:

Land tenure map - indicates the present and proposed status of the public land and outlines the private property boundaries.

Vegetation/fuel type map - vegetation types with similar fuel accumulation or similar fire behaviour patterns are delineated.

Travel time map - shows travel times from work centres to various parts of the region. It allows a reliable estimate of the time taken by a forest attack crew to reach any point in the region and assist in determining relative priorities for fire protection expenditure.

Fire origin map - historical ignition points are colour coded by cause. The map indicates likely fire sources and influences the positioning of fire protection works.

Burning history map - records fuel reduction, regeneration burns and wildfires of the previous ten years. Areas are classified according to the surface area covered by the fire. Categories are "less than 20 per cent", "twenty to fifty per cent" and "greater than 50 per cent".

Assets map - highlights the requirements for specific protection. It includes fire sensitive areas, fixed installations, settlements, visitor congregation areas and areas subject to special management or other constraints.

Additional maps or variants of existing maps, such as aircraft/helicopter travel and turn-around times can be added to this series where relevant.

The Strategy Plan consists of a short descriptive text detailing objectives, constraints and operational instructions and a map that outlines the current and proposed fire protection activities. The facilities are designed to limit the occurrence of fires, decrease the impact of major fires and allow more effective suppression.

The Strategy Plan includes details on detection, access, fuel treatment (eg burning, slashing, grazing), and provision and maintenance of facilities (eg firebreaks, water points, refuges and air attack facilities). The planning process enables the integration of management burns for flora and fauna management when such requirements are made known by the relevant sections of the Department. Fuel reduction burning is the most significant single fire prevention tool used. It is used in accordance with the "Department's Policy on Fuel Reduction Burning".

Burning zones are indicated on the Strategy Plan as follows:

Priority 1 Burning Zones - located principally around specific assets such as townships, settlements and plantations. The aim can vary but in dry sclerophyll forest is typically to maintain fine fuel below eight tonnes per hectare with 90 per cent of the ground area burnt over in any one operation. The burning rotation depends on the rate of fuel accumulation, but could be as frequent as once every three to five years.

Priority 2 Burning Zones - strategic corridors of wide continuous belts of forest in which the fuel is reduced by burning to provide substantial barriers to the spread of wildfire. Some strategic corridors are integrated with Priority 1 Burning Zones and other means of fuel modification. The aim is to maintain fine fuel below 12 tonnes per hectare with 80 per cent of the ground area burnt over in any one operation. The burning rotation depends on the rate of fuel accumulation, but could be as frequent as once every four to eight years.

Priority 3 Burning Zones - areas of forest where fuel reduction is necessary to prevent destruction of forest values and to complement higher priority works. Ridge-top lighting, aerial ignition and ground ignition are all acceptable means of achieving this fuel reduction. The burning rotation depends on the rate of fuel accumulation, but could be as frequent as once every six to twelve years.

A Works Program map is prepared annually, based on the Strategy Plan map and the records of past operations. It is prepared on a rolling three-year basis to provide continuity of operations, particularly linked operations (such as preparing control lines this year for burning next year) and to provide flexibility to take advantage of seasonal conditions. The annual budget derives from the Works Program map.

Large scale Fire Protection Unit Plans are required to record small but significant items of operational and ecological importance, which may necessitate constraints to fire protection works, and particular hazards/dangers associated with certain areas. Fire Protection Unit or Burning Unit Plans have been developed to record this information and form the basis for works direction.

Input to the Planning Process

The Regional Fire Protection Officer is responsible for preparation of the plan. He is expected to generate a wide spectrum of input to the Strategy Plan both during the preparation phase and when the first draft has been prepared.

Information input is obtained from specialist officers from all functional areas within the region/department, and identified interest groups in the region. This is done by personal approach to the groups and attendance at meetings where the fire protection of their specific interest area is discussed. These groups include fire brigades, municipal fire committees, conservation groups, field naturalists, birdwatchers, apiarists and Committees of Management.

Formal input to the draft is requested from the Regional Management Team and functional Departments of CFL (ie Fire Protection, National Parks and Wildlife, Land Protection, State Forests and Lands), and amendments made in the light of these comments. Input is also sought from the general public through newspaper advertisement, both locally and in Melbourne. The plan is displayed for inspection at appropriate sites within the region and in the Melbourne Head Office for six weeks. The plan is further amended in the light of public comment.

The final approval process within the Department involves the functional Divisions at a planning issues meeting, where unresolved matters, if they exist, can be resolved.

The plan can be revised at any time if circumstances change, and must be reviewed at least every five years.

CONCLUSION

Though time consuming to prepare initially, the fire protection plan is simple to understand by other than fire protection people, and is readily updated and amended if necessary. The input from the public and specialists from a wide range of disciplines ensures that the fire protection objectives are met with the minimum of environmental and social impact.

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THE POLICY FRAMEWORK AND MANAGEMENT FOR FIRE PROTECTION IN SOUTH AUSTRALIAN CONSERVATION RESERVES

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SUMMARY

Reserve managers in South Australia have certain statutory obligations to manage bushfire problems in parks and reserves. These responsibilities are addressed through the development of policies and by management planning. A co-operative approach is taken on a regional scale to the problem of potential bushfire, but many perceived problems reflect unrelated adverse social reactions to the proclamation of parks and reserves in rural areas. It is therefore important to ensure protection programs address actual rather than perceived hazards.

POLICYAPPROACH

Legislative Framework

Legislation applying to lands reserved for nature conservation in South Australia prescribes a list of objectives that must apply to those lands. These objectives are similar to those applying to other states and include:

(a) the preservation and management of wildlife (native plants and animals)

(b) the preservation of features of geographical natural or scenic interest; and

(c) the prevention of bushfires and other hazards (National Parks and Wildlife Act, 1972-81 Section 37a, c and g).

It is quite conceivable that many circumstances could arise where fire management works could adversely impact on the preservation of wildlife and natural features. The legislation therefore contains an inherent contradiction that park managers must address.

The obligation of the Crown to pay regard to fire protection matters in lands under its control is further prescribed in the Country Fires Act. The relevant

The obligation of the Crown to pay regard to fire protection matters in lands under its control is further prescribed in the Country Fires Act. The relevant Minister has the duty to take reasonable steps to reduce the danger of the outbreak of fire on vested lands or the spread of fire through those lands (Country Fires Act, 1976 Section 7(1)).

Fire Management Policy

The first stage towards developing management practices that meet the statutory requirements (including contradictions) is the development of a policy. The South Australian National Parks and Wildlife Service policy on Fire Management and Protection includes a number of principles:

(a) recognition of the adaptation of natural communities to fire and the impracticality of any objective that aims to eliminate fire from natural areas;

(b) the environmental alteration following European settlement, the rarity of unaltered areas and the consequent need to preserve and manage what areas remain;

(c) the danger to the community from wild fire and the need to provide protection may change natural communities;

(d) recognition of the role of fuel reduction burning as a tool to reduce wild fire intensity in areas that have been identified as potential hazards; and

(e) recognition that fire protection is best achieved on a regional scale where the community can alleviate potential fire hazard through wise land use planning and that protection in areas of high fire hazard cannot be guaranteed (pp 25-29, Policies Document, Third Edition 1986, South Australian National Parks and Wildlife Service, Department of Environment and Planning).

The policy describes a number of fire management objectives:

(a) to protect life and assets, foster sound use planning over areas of fire hazard, maintain biological diversity, protect special natural features and prevent degradation of land from erosion and noxious pests;

(b) to prepare fire management plans for all fire-prone parks;

(c) to clearly identify the administrative arrangements for suppression operations in advance of a wild fire;

(d) to designate fuel reduced zones in parks in consultation with neighbours;

(e) to establish a priority for fire management works on areas of high visitor use and parks with adjacent assets of high financial value;

(f) to provide a proper supression infrastructure;

(g) to define co-operative arrangements with community groups and fire management and emergency services;

(h) to implement comprehensive training programs and research projects;

(i) to prescribe park closure during dangerous fire weather conditions; and

(j) to encourage land use planning in the vicinity of parks and implement zoning and other planning arrangements to mitigate against the potential for adverse impact of fire, particularly high intensity fire.

Fire Management Plans

The next stage in management practice is the preparation of fire protection plans. These plans are prepared for individual parks and cover park management objectives, the nature of the fire problem, fire management resources (human, plant, communication, supplies), fuel management strategies, wild fire prevention, and supression action plan.

These comprehensive plans are prepared in conjunction with State and local fire control and local government organisations. They are released in draft form for public input and comment and the final form is regularly updated by field staff.

FIRE AS A PROBLEM

Fire as a Social and Political Issue

Expenditure of increasingly limited resources on fire protection must inevitably be directed to those locations and circumstances where a fire hazard exists. For fire to be a potential problem to the community there must be tangible assets (lives and/or property) under threat. It follows that protection resources should be concentrated where possible wild fire has the potential to cause damage.

Conservation lands are perceived to pose major threats to rural and urban fringe communities. These lands are often timbered and rugged and have been previously found unsuitable for urban or agricultural use. As vacant crown land these areas do not carry the status as fire threats that they obtain following proclamation as national parks. Unlike productive forestry land the classification of land as national park has its social and political genesis in affluent urban populations. Consequently the proclamation of a national park is often strongly resented by rural communities, particularly if it is accompanied by restriction of local traditional rights for access to natural resources. The resentment often finds expression in strong and public criticism of protection policies and is often compounded by limited availability of park management resources following proclamation.

Timbered national parks are perceived as a threat to surrounding lands. However, statistics reveal the converse is the true situation. In South Australia during the fire seasons 1974 to 1986 inclusive, statistics of 387 fires on lands dedicated as Reserves or managed by National Parks and Wildlife Service, revealed that 95 fires entered Reserves from adjoining properties, burning 155 164 hectares of Reserve; 20 fires, which started in Reserves, escaped into adjoining properties, burning 10 098 hectares of private property; and 272 fires which started in Reserves were contained within those Reserves, burning 124 713 hectares (Fire Statistics 1974-86, Protection Management Unit, South Australian National Parks and Wildlife Service).

For the park manager, addressing the problem of fire management should therefore often involve social and political issues rather than physical problems. If this is the case then the protection question should be approached in a social manner with emphasis on communication, community relationships and ready mutual co-operation where hazards exist. Often the resentment and distrust of conservation land use decisions takes decades to overcome.

The danger for the local park manager in these circumstances occurs where the manager undertakes visible protection works as a palliative to local resentment rather than addressing potential fire problems. A great deal of money can be wasted on useless burning programs and ill-considered trail construction and a great deal of needless damage done to the areas purported to be established for conservation purposes.

The "politics" of fire management in national parks is not confined to rural communities. There has been a number of forestry land use debates in Australia where the issue of fire management in national parks (or perceived lack of it) is used to reinforce a partisan position. The result of the consequent polarisation between productive forestry and nature conservation is repeatedly seen in public squabbling between forestry and park agencies in fire management forums, coronial inquiries and media debates.

My remarks are a consequence of interstate experience; South Australia is largely free of the debate I have alluded to. This may be because of the absence of tracts of productive native forest (and thus the opportunity for controversy) or history of a co-operative approach to management issues.

This Workshop clearly presents an opportunity to raise these and similar matters for constructive discussion and it is in this context that the matters are mentioned.

Fire as a Physical Issue

The legislative and policy framework (paragraph 1) reflects the reality that fires from conservation lands obey the laws of combustion physics and, given the right set of circumstances, will have the potential to threaten lives and property. This potential must be addressed in accordance with legislative and community expectations.

There are a number of fundamental aspects of fire as a physical issue that influences park management decisions:

(a) intensity is the fire behaviour parameter that poses the hazard in the majority of circumstances;

(b) potential fire intensity can be identified at individual sites by applying fire behaviour models to measured information;

(c) a hazard from potential fire intensity can be ameliorated by either reducing or modifying fuel availability or ensuring that the asset under threat is not at that site in the first instance;

(d) if a course of management actions do not effectively address identified hazard then that course of action should not be undertaken; and

(e) fire is often a problem on a regional scale and fire prevention or hazard amelioration should be addressed as a regional land use and planning issue rather than concentrating on a single land tenure.

Fire as a Conservation Issue

So little is known about the composition and dynamics of the various ecosystems within conserved lands that it is almost impossible to make any management judgements at all about the use of fire as a management tool or the impact of fire management programs on the environment. Judgements are often made on particular species or simple habitat issues.

In the absence of sound knowledge a good rule of thumb appears to be that interference with natural communities in conserved lands should be avoided unless there are sound reasons to the contrary. Many areas are in such a degraded state following European land use impact that a prolonged recovery phase is necessary to allow secondary successions to proceed towards a near natural condition. Sound reasons for interference would include fire management works (eg fuel reduction, road and break construction) in areas where such works would be effective in easing identified fire hazards.

The South Australian National Parks and Wildlife Service policy on controlled burning is as follows:

> "It is recognised that unplanned fires will continue to occur and will influence decisions on future management of the burnt areas. If it is necessary to provide some protection against the adverse impact of unplanned fire intensity by fuel reduction burning then the Service also needs to recognise that there may be changes to plant and animal communities as a direct result of the fuel reduction burning program.
>
> The practice of 'burning off' or fuel reduction burning can be a valuable management tool to reduce the fuel available to a wild fire and thus the potential intensity of that fire. A fuel reduction burning program may therefore be undertaken in areas of potential fire intensity hazard that have been identified through land use planning and where such a program will achieve fuel reduction objectives. Broad areas of burning off achieves little practical protection and has a probable adverse environmental impact when undertaken on a frequent cycle. The most reliable protection for the community (and conservation reserves) can be achieved when land use planning recognises and makes allowance for fire hazards. Sound land use

planning should be followed by planning for fire protection works and emergency services. The protection from fire of development and human activity located in areas of high fire hazard cannot be guaranteed."

This statement needs to be viewed in the South Australian context. The fire management problem is generally focused onto two discreet situations:

(a) urban fringe forested parks in a hilly landscape with housing long established often in potentially dangerous fire circumstances;

(b) very large parks with mallee vegetation growing on partially consolidated sand dune systems.

The first circumstance requires intensive fire management practices in conjunction with local Government and Country Fire Services. This will often include controlled burning.

The second circumstance requires boundary fuel reduction and access works. The mallee vegetation systems do not accumulate fuels beyond eight to ten tonnes per hectare and with the potential instability of devegetated sand dunes little useful purpose would be gained with a broad scale controlled burning program. The boundary management policy is undertaken in conjunction with local landholders and the Country Fire Services and involves physical modification and fuel (slashing or rolling) rather than burning.

Fire as a Planning Issue

Whilst fuel management practices can be used to address problem areas it makes far more sense to not have the problem within fire hazardous locations in the first instance. In many areas the damage has already been done by previous inappropriate subdivision and development, but sound land-use planning and development control can ensure folly is avoided in the future. The South Australian Government has prepared a planning instrument under the State's planning framework whereby fire hazard is described by map and development is directed away from sites and areas with an unacceptably high level of bushfire hazard. The instrument applies to an area nominated as the Mount Lofty Ranges Bushfire Prone Policy Area (South Australian Supplementary Development Plan for the Mount Lofty Ranges Bushfire Prone Policy Area).

The prescribed development control principles include:

(a) precluding development or subdivision by location according to fire threat;

(b) describing suitable allotment size to the incorporation of protection measures;

(c) describing subdivision layout to accommodate safe fire fighting;

(d) identifying fire dangerous topographic circumstances to avoid dwelling construction;

(e) water supply, pumping and fitting requirements; and

(f) landscaping requirements and vegetation management.

The planning instrument is supported by Building Act Regulations which include prescriptions relating to defined local government areas, and floor, wall, window and roof materials and construction methods (Specification 16.1a of the South Australian Building Regulations 1973, as amended).

As most of the fire prone areas are in proximity to conservation reserves the National Parks and Wildlife Service has a vital interest in promoting sound land-use planning. This is particularly so if injurious and heavy-handed protection practices are to be minimised in protecting adjacent foolishly located buildings or subdivisions. The development of these planning policies was initiated by Commonwealth and State park agencies, and continues to be promoted in South Australia, New South Wales and the Australian Capital Territory.

CONCLUSION

Conservation managers have the same obligations as any other landholder in protecting the community to the greatest practicable degree against the adverse impact of potential wild fire. It is considered important to respond to actual fire hazards rather than perceived problems that may reflect unrelated social or professional dissatisfaction with nature conservation land use decisions. Actual fire hazards therefore need to be soundly identified on a regional scale and addressed as a regional problem, rather than isolated to particular land uses. In this way the most effective protection strategy and development zoning program can be developed on a planned basis in a co-operative manner covering the broader community.

SETTING CONSERVATION AND PROTECTION OBJECTIVES - CONFLICT FOR MANAGEMENT IN THE BLUE MOUNTAINS (1983-1986), A CASE STUDY

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SUMMARY

New South Wales legislation in the environmental field has imposed a set of often conflicting objectives of fire protection and conservation of natural and cultural resources on managers of National Parks. This paper examines a case study of the resolution of these potential conflicts in the Blue Mountains area in the period 1983 to 1986.

Over the three-year period examined in this paper significant improvements in fire management of the Blue Mountains region of New South Wales have occurred by means of strategic fire planning and the meeting of responsibilities under the Environmental Planning and Assessment Act (1979). This approach has replaced a traditional and reactive distrust between fire organisations. An improvement in co-operative arrangements between local fire authorities and an increasing awareness of the significance of the Blue Mountains natural resources also has resulted.

The approach adopted was based on the premises of an understanding of the resource to be managed, determination of various management options, and effective communication with other fire authorities about the Service's activities. This provided a better forum with other authorities in dealing with the local fire problem. This approach enabled important advances to be made in improving conservation and protection objectives in the Blue Mountains.

INTRODUCTION

Unlike neat and ordered scientific experiments with their conclusions and finite experimental settings, the management approach adopted represents a continuum of endeavour and evolution of new ideas of management. There are never any necessarily tidy outcomes or conclusions in the process of refinement of management approaches. As such, District management staff are still improving on the initial preparatory work laid down in that period.

The Blue Mountains Setting

The Blue Mountains are dominated by rugged sandstone cliffs, deep gorges and elongated plateau tops. Typically, this region contains woodlands and open forests, with some rainforest areas confined to the basalt caps and sheltered gorges. Smaller pockets of heaths, sedgelands, swamps and mallee woodlands occur sporadically throughout the Blue Mountains' environment.

The area is located 60-120 kilometres west of Sydney and extends north and south for over 200 kilometres. Conservation reserves including the Blue Mountains National Park, which surround the Blue Mountains city, the Kanangra Boyd National Park, the Wollemi National Park (partly administered by Blue Mountains district) and Pantoneys Crown Nature Reserve totalling some 430 000 hectares (Figure 1). Some 64 000 residents are found within the Blue Mountains city which extends as a series of ribbon developments along the Great Western Highway.

Towns are located on a dissected and tilted plateau which has its maximum altitudes to the west at about 1 100 metres, descending to about 100 metres in the east. During winter the area is typified by dry cold and strong westerly winds with mean monthly minimum temperatures between 3^{o} to 5^{o}. Moist easterly winds become more predominant in summer and autumn, and with the orographic uplift of the elevated plateaux, often sustain long periods of mist and rain. Mean monthly maximum temperatures vary between 20^{o} and 25^{o} and temperatures may occasionally reach 30^{o} or higher in the upper Mountains. Rainfall ranges between 800 mm and 1 500 mm per annum, depending on elevation.

Historically, the area has been subjected to intense bushfires, the most recent of which occurred in 1952, 1957, 1968, 1977 and 1982. Prior to 1982 these fires caused substantial property damage and loss of life. More than 400 bushfires have occurred in the Blue Mountains area in the past 28 years of accurate records.

Management Framework

Legislation

The Bushfires Act (1949) places an obligation on all management agencies to prevent the occurrence and spread of fire, while the Environmental Planning and Assessment Act (1979) requires any fire management activity to be assessed in relation to potential impact. The National Parks and Wildlife Act (1974) also requires the preparation of a plan of management for each National Park and Nature Reserve. The plan of management shall have regard to the following objectives that refer particularly to fire management:

(a) the conservation of wildlife;

(b) the preservation of each National Park, together with the protection of the special features of the park;

(c) the prevention of any works adversely affecting the natural condition or special feature of each National Park;

FIGURE 1
Map of Study Area

(d) the preservation of each National Park as a catchment area; and

(e) the protection of each National Park against fire and erosion.

In New South Wales the requirements of the above legislation provide conflicting ideas about fire management in National Parks such as the Blue Mountains. The core issue of this conflicting legislation is clear; that of weighing up the detrimental effects of bushfires with the overriding priority of protecting life and property.

The Fire Management Setting in 1983

Many people in the local community have perceived the local park as the cause of the fire problems in the Blue Mountains. After each major fire event, there is a clamour for more fire trails and aerial burning in the more remote areas of the park, even when the cost-benefit of these programs has never been adequately evaluated. This was very evident after the 1968 fires which destroyed much life and property.

> "The 1968 fires burned for many weeks before emerging from the valleys under severe fire weather conditions and destroying homes. The park was seen by many as the cause of the fire problem. A good deal of advice was offered by established fire authorities seeking to control the problem. More fire trails and extensive aerial burning were the main suggestions. One Shire even advocated burning the bush wherever and whenever it would burn." (Weir 1978)
>
> Analysis of the fire situation by the National Parks and Wildlife Service suggested otherwise, and in particular found that:
>
> - "In 1968 fires burned unattended for many weeks.
> - The accepted method of fire suppression was to deal with only the hot spots emerging from the bushland.
> - In most places, the park was well removed from urban development.
> - No specific building requirements were in force to provide protection for home owners." (Weir 1978)

This perception that the park was a fire problem continued to be held, and after the 1982-83 fires pressures were again placed on staff of the National Parks and Wildlife Service for significant modification of the park's natural resources by extra fire trails and aerial ignition of remote areas of the park. Advances had been made in the planning guidelines of fire-prone areas in urban bushland settings, but there was little evidence that they had been vigorously implemented, despite the succession of fires since the advent of these planning provisions in 1979. Similarly, bushland within urban areas and between the park boundary and the urban areas had been overlooked by the advocates of more trails and burning the park. Clearly, marked differences in opinion prevailed in 1983 as to how fire protection of urban areas could best be achieved. The scene was therefore set in

1983 for District staff to show initiative and direction in integrating fire and conservation objectives.

Development of Conservation and Protection Objectives

Fire History

Fire history records were collated from various local sources, including National Parks and Wildlife Service, Metropolitan Water and Sewerage Drainage Board, Forestry Commission, local Councils and Shires, and individuals. Wherever possible these fires were mapped onto a series of overlays. A computer database of fire history was compiled and tables and graphs were prepared from this information. Figure 2 shows an example of a graph of areas burnt and number of fires per season since 1960.

Other general trends obtained from this analysis were that:

(a) less than half the fires in the study area started in the park;

(b) only five per cent of the fires started in the park burnt into adjacent property compared to the 87 per cent of fires starting outside the park burning into it;

(c) 18.5 per cent of all fires were caused by lightning strikes;

(d) 12.5 per cent of all fires were from escaped burn-offs;

(e) as a result of escaped burn-offs bushfires in September (17.4 per cent) rivalled the bushfire months of November (12.4 per cent), December (22 per cent), January (16 per cent) and February (16.3 per cent) in terms of the proportion of total fires;

(f) human-caused fires started much earlier in the fire season than those started by lightning, causing an extension of the fire season into the months of Spring (Figure 3).

Analysis of fire history provided for improved co-operative protection objectives by indicating where problem areas existed with respect to fire frequency. It also assisted in eliminating some of the historical myths about fire origins and causes that prevailed in the debate on fire issues.

Natural and Cultural Resources

There was little information in a usable form about the pattern and the distribution of natural and cultural resources for the Blue Mountains area prior to the start of the fire planning exercise. The design of the data collection and storage occurred at a time of important advances in the development of "PREPLAN"; the computer-based fire and natural resource management suite of models (Kessell, Good and Potter 1982). An area of 450 000 hectares was sampled at a 25 hectare (500 m x 500 m) grid cell size, with the immediate Blue Mountains City Council area being sampled at a 4 hectare grid cell size (200 m x 200 m).

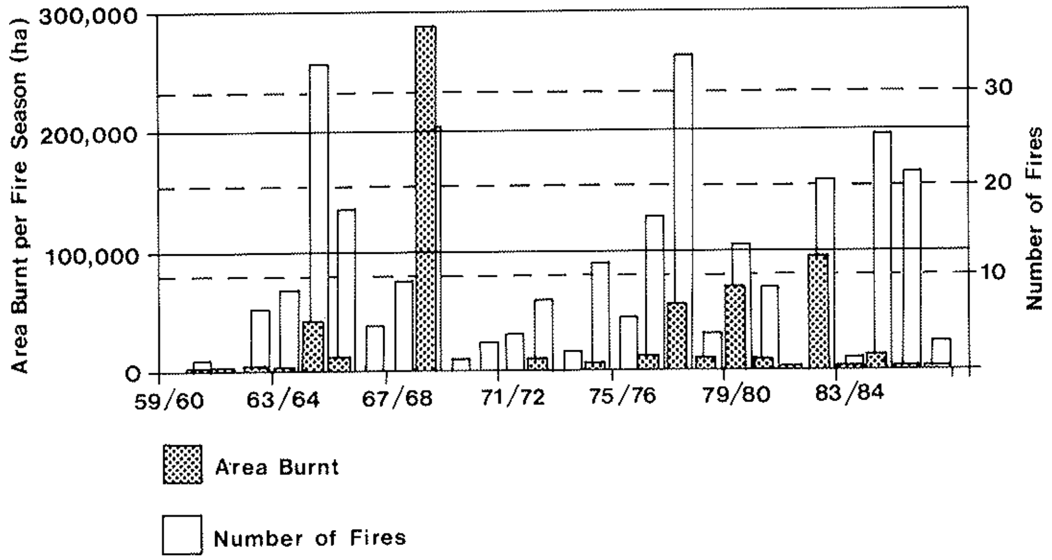

FIGURE 2
Pattern of area burnt and number of fires per fire season in the Blue Mountains (1959-1987)

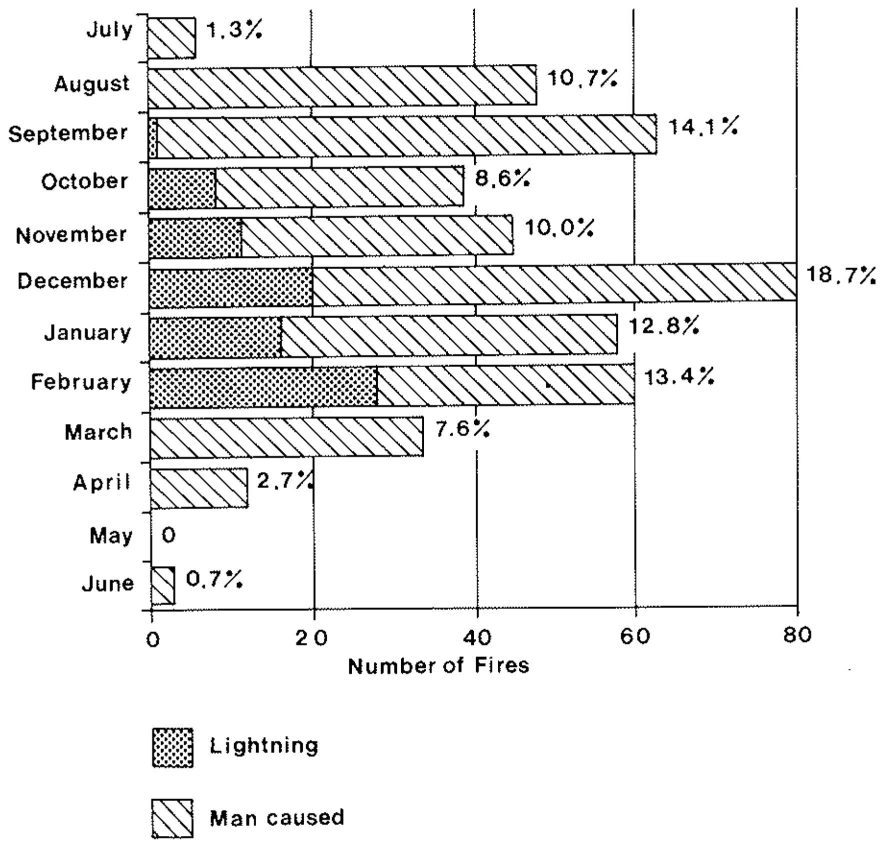

FIGURE 3
Seasonal occurrence of lightning and man-caused fires in the Blue Mountains (1959-1987)

Vegetation for the entire area was mapped, and a program of fuel and vegetation surveys implemented. All known cultural resources were recorded and all records of fauna collected from Museum and local records.

With particular reference to fire management and the objectives of conservation and protection, the information provided:

(a) An understanding of the complexity and diversity of the Blue Mountains flora with 90 distinctive vegetation types being mapped.

(b) The distribution and abundance of each of the vegetation types, and their conservation status.

(c) The location of rare and endangered flora species and an appreciation of the sensitivity of some critical resources to fire and other disturbance factors.

(d) An understanding of the spatial pattern of the vegetation units.

(e) An assessment of the fuel levels within each vegetation type. (This sampling was initially designed to accommodate the MacArthur fire behaviour models, but was later revised to provide information for the Rothermel fire behaviour models.)

(f) Fuel accumulation curves which were derived from data collected on fuel surveys in different vegetation and fire history classes.

(g) The presence and absence of fauna and the extent of local extinction of species.

(h) The pattern of species movement for some species, particularly birds in late winter and spring.

(i) The location of historical or cultural resources, including the possible risk of impact from a particular fire event.

Fire Weather

Historical weather data were analysed and the Soil Dryness Index (SDI; Mount 1972) was introduced. This was found to be a more accurate drought index in the more permeable sandstone soils than the Keetch-Byram drought index.

An analysis of the historic records identified the following:

(a) Wildfires that caused significant damage only occurred during periods when the soil dryness index was at a very high level.

(b) Property loss occurred in the major fires during periods of high fire danger index but extremely high soil dryness.

(c) Potential opportunities for prescription burning in autumn were identified on a monthly basis by averaging the available "window" of conditions suitable for prescription burning.

(d) Patterns of unusually high soil dryness through winter could be linked to risky conditions for burning in the following spring.

Appreciation of Fire Behaviour

Analysis of the natural resource, the fire history, and the fire weather information contributed to an improved understanding of the behaviour of the fires in the Blue Mountain area in the following ways:

(a) Wildfires occurred regularly during the fire season and were generally associated with mild and stable weather patterns which allowed rapid fire suppression.

(b) Serious fires in extreme conditions occurred on a nine to thirteen year cycle and only in a narrow window of probability of two days in every 200 days during a six month fire season.

(c) Fires travelling from west to east under the prevailing westerly winds would burn into areas at lower elevations and hence into areas of higher temperatures, lower relative humidities and higher levels of soil dryness. The same fire fronts would tend to cut across the fingers and clusters of urban development which paralleled the sinuous Great Western Highway.

(d) Fires did not respect boundaries, and were a community responsibility requiring a co-operative effort.

(e) Natural areas of bushland which occurred within and adjacent to the Blue Mountains city needed fuel reduction, since these maintained the momentum of fires within urban areas.

(f) Given the opportunities to use remote area fire fighting techniques in the more distant parts of the park, the most dangerous fires tended to be those which started close to urban areas.

Improved Conservation and Protection Objectives

Some of the key conservation concerns held by local District management were the frequent intense wildfires started by human causes mostly of deliberate origin; the use of bulldozers in creating new trails in the highly erodible sandstone derived soils; and the fire effects of large scale backburning operations on the vegetation and wildlife habitat. The simplistic notion of "fire protection" in isolation needed revision in the light of environmental objectives and better knowledge of fire behaviour and fire effects.

Minimising the risk of major wildfires occurring

This simple objective was important given that the majority of wildfires were of human origin, and that the objective was consistent with both protection and conservation endeavour. Management objectives arising from the Service's resource data collection and analysis were:

(a) The policy of autumn burning only by the Service was reinforced, which minimised the potential for "September escapes", and provided protection for the native flora and fauna during the biologically active spring period. Other agencies were encouraged to follow this practice.

(b) The weekly Soil Dryness readings were provided to other fire management authorities, which allowed the authorities to independently assess the danger of burning-off or of wildfires.

(c) Fire readiness was determined by the Soil Dryness readings. The predicted weather conditions, together with the period of the fire season, refined this readiness in terms of staff and equipment availability at strategic locations.

(d) Advice to the public about the fire danger, including fire restrictions in popular camping destinations, was determined from Soil Dryness readings. These restrictions, if imposed, were in addition to the Total Fire Bans issued by the minister for Emergency Services. The fire source data provided information to the historical problem locations of campfire escapes.

Maximising the protection of property

It was clear that there needed to be a firm inter-relationship between town planning, knowledge of fire hazards and appropriate fire protection measures for property. The following approaches were adopted:

(a) The Service prepared an annual fire behaviour potential map under set weather conditions, which was provided to fire management authorities. The Service developed its annual program of fuel reduction based on the predicted high fire potential areas in the boundary areas of the park.

(b) A co-operative venture with the town planning department of the Blue Mountain City Council developed a computer-based land capability analysis, which included fire hazard assessment. The assessment of the remaining rural lands of the city allows the Council to recognise classes of bushfire hazard in these areas prior to planning further subdivisions.

(c) A co-operative planning effort with fire control and town planning sections of the Council, and supported by the Blue Mountains Bushfire Prevention Assocation, determined the strategic fire protection advantages available on the northern side of the city. This planning included the careful assessment of sensitive natural environments, as well as locating natural and cultural fire boundaries.

(d) The Service became involved with co-operative fuel reduction works with the local brigades in the complex boundary areas adjacent to the park.

(e) The Service placed emphasis on co-operative fire management through the local committee.

Minimising the negative effects of wildfires

The decision to suppress a wildfire may arise as a consequent of proximity to property (and therefore a threat); potential impact of the natural resources; impact on catchment values; and lack of suitable control lines prior to fire reaching property. The operational sequence undertaken to manage fire included:

(a) analysis of potential fire behaviour and of the proximity of sensitive natural environments and natural fire control advantages;

(b) where wildfires were close to urban areas, using co-operative fire suppression techniques, and making use of the combined existence of tracks, rakehoe lines and subdivision perimeters; and

(c) where wildfires were in remote locations and still small in size, using remote area attack of fires, supported by helicopters for field reconnaissance, crew transport, water bombing, and aerial burning.

Before committing personnel on these fires the following guidelines were used:

(a) extensive use of fire simulations for determining fire perimeters under sets of fire weather conditions;

(b) assessment of the effectiveness of natural barriers;

(c) determination of the safety of field personnel under different fire behaviour conditions; and

(d) continuous monitoring of fire weather at the base and in the field.

Minimising the negative effects of fire management practices

In the management of both wildfires and prescription burns, an attempt was always made to minimise the impact of the management operation. This included:

(a) undertaking a review of environmental factors for prescription burning;

(b) planning the prescription burns in detail, which involved determining the pattern and intensity of the fires over the prescribed areas, and where possible, excluding important conservation resources such as regenerating areas, swamps, heath and rainforest from burning;

(c) where possible, using fire control lines such as rakehoe lines and natural boundaries as fire perimeters;

(d) encouraging the full application of the Environmental Planning and Assessment Act for major (non emergency) developments (eg roads) near parks;

(e) changing the season of burn to avoid burning during the breeding season of small mammals and birds, or to achieve more effective burns on basalt areas such as Mount Wilson; and

(f) devising fire control strategies that took into account both protection objectives (fuel reduction near urban areas) and conservation objectives (locating permanent fire perimeters to avoid critical habitat areas).

Maximising protection for conservation resources

Protection of the conservation resource improved as a result of (a) vegetation, fuel and fauna surveys which allows a better understanding of the nature conservation resource present in the Blue Mountains; (b) the recognition of important flora and fauna habitat areas, as well as a better knowledge of fire effects on key flora and fauna; (c) careful application of fire in remote areas; and (d) careful use of fire in catchment areas.

CONCLUSION

Fire management conflicts had arisen between fire management authorities because of deep-seated views about broad area burning, firetrails, and disputes over fire control authority in National Parks. However to their credit, the local fire management authorities have accepted the requirements of the Environmental Planning and Assessment Act. Protection and conservation issues have been addressed in forums which had previously been more singular in their objectives. The benefits of objective resource information gathering presented at these forums has been better decisions and less time wasted in resolving complex issues.

In all, this approach will serve to improve the chances of retaining both the cultural and natural heritage while improving property protection. Large fires will still occur in the future and will make the dual responsibility difficult to achieve at times. Fire authorities will need close co-operation and liaison to achieve optimum protection while planning protection and fire management strategies.

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SETTING OBJECTIVES FOR MANAGEMENT OF NATIONAL PARKS AND NATURE CONSERVATION RESERVES

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SUMMARY

Clear objectives must be incorporated into management plans for conservation areas. These ensure that resources are focused, progress can be evaluated, and provide staff with a sense of direction and purpose.

The paper provides a checklist for good objective setting and looks briefly at three examples from Western Australia.

INTRODUCTION

In any human endeavour, success is more easily achieved if clear objectives have firstly been established, and if they are understood and agreed to by all who can influence the outcome. This fundamental principle applies particularly to the management and protection of conservation reserves, because:

(a) our reserve classification system is still evolving - the relationships between tenure and purpose are often confused, or disputed;

(b) the ecological data base upon which management must be based is inadequate, even non-existent in some instances;

(c) the discipline of nature conservation management is still young and many staff are inexperienced; and

(d) the community's demands on, and expectations of, conservation reserves range across a wide spectrum so that almost any management action is controversial.

Taken together, these factors can provide an excellent set of excuses for not formulating (or at least not publicly stating) explicit management objectives for conservation reserves. To the list can be added the view that since most Australian conservation and land management agencies are seriously under-resourced, statements of objectives can simply become statements of impossibility - ie an exercise in futility.

1. *See Endnote for definitions.*

I take a different view. Irrespective of the state of our knowledge or the size of our budgets, I believe it is essential that the objectives of management are made explicit. This is because:

(a) the effort of thrashing them out internally is a necessary mental discipline for an organisation;

(b) written objectives provide a yardstick against which progress can be measured;

(c) objectives provide a focus for other activities, such as research, and enable priorities for budgeting and resource allocation to be set;

(d) progress in achievement of objectives can be reported, and this is a form of accountability for funds spent;

(e) a statement of objectives provides an opportunity for the community to see where the agency is trying to go, and to indicate whether or not it agrees;

(f) objectives provide district staff with a sense of direction and purpose; and

(g) once objectives have been set and agreed upon, subsequent planning becomes easier.

Statements of objectives (elaborated into documents such as stratetic plans, management plans or protection plans for specific reserves) also provide a "Statement of the Art" - at the very least a Mark I or baseline approach which can be continuously refined as research findings are applied, the results of monitoring come in or new factors emerge. At the very best they provide an opportunity for scientists and managers to really demonstrate their professional know-how, and implement the fruits of research and operational experience.

There is nothing new about all this. Most conservation reserve managers in Australia are keen proponents of the concept of management based on formal planning processes. The setting of objectives is the essential primary step in this process.

Other writers (eg Burrows 1985; Hopkins 1985) have dealt with the sort of operational factors which need to be taken into account in developing strategies for the protection of specific conservation reserves. Rather than go over this ground again, I prefer to try to develop a set of principles which can be applied to the process of setting of objectives, and then to provide examples and see how we are matching up in Western Australia.

First, however, it is necessary to briefly examine the resource being managed, for which objectives must be set.

The Resource

Conservation reserves in Australia vary immensely in their purpose, size, geographic location and the ecosystems they contain. For example, there are three broad categories of reserve:

(a) Those where the purpose of management is primarily wildlife conservation - eg nature reserves.

(b) Those where the primary purpose is wildlife conservation, protection of cultural values and public enjoyment - eg national parks.

(c) Those where the primary purpose is sustained production of a natural resource (water, timber, fish, etc) but where wildlife conservation and public enjoyment are also provided for - eg State forests.

Each of these requires a different thrust of management. To add to this complexity, reserve size (in WA alone) ranges from less than one hectare to a million and a half hectares; reserves are located in the tropics, the desert, the wheatbelt, the oceans, in forests and on islands; and ecosystems to be conserved vary from rainforest to spinifex.

There are two problems presented to managers by this complexity. The first is the sheer size of the planning task. This can only be overcome in time, and by determined effort and intelligent "short-cuts" such as dealing with groups of similar reserves as an entity (Wallace and Moore 1987). It is also essential that planners and managers have the necessary technical support to facilitate the planning task. I regard these as basically policy and administrative problems, and beyond the scope of this paper.

The second sort of problem in such a complex system is more difficult - how to find a systematic way to develop and present objectives. One answer is to have a "checklist" of principles which can be used both in the preparation and the assessment of objectives developed for the management of conservation reserves, and this is the aspect I now wish to pursue.

The Principles

I believe that a satisfactory set of objectives for a conservation reserve must comply with eight principles.

1 *The objectives must reflect the purpose for which the reserve was set aside.*

Unfortunately, this is not as simple as it sounds. A surprising number of Western Australian conservation reserves are managed in unexpected ways. For example, hunting some species of native animals is permitted on some nature reserves, and open cut mining occurs on others and in State forests set aside for sustained yield of timber. Beekeeping, involving introduced honey bees, is widespread in national parks in the south-west of the State. These anomalies reflect historical or political decisions rather than the deliberate planning processes of professional conservationists. Experienced planners accept the reality of certain unalterable political and social constraints; nevertheless, it remains a fundamental requirement that management objectives should reflect reserve purpose, as defined for each State.

2 *The objectives must reflect the nature of the ecosystem to be managed.*

Almost every reserve differs in terms of landform and biological make-up, and many have special values such as rare species, plant or animal communities or landforms.

In Western Australia there is a general objective (WA Department of Conservation and Land Management 1987) to maintain as high a level of species diversity as possible in conservation reserves, except in situations where particular species are deliberately favoured (eg Burbidge *et al* 1986). This is a contentious issue, both philosophically and at the workface, particularly when two favoured species in the one reserve have quite different habitat requirements (Christensen and Maisey 1987).

These very difficulties emphasise the importance of managers making the effort to think out and state their objectives. Without this, field staff have no point to steer towards, and management can become literally "aimless". From a scientific point of view a lack of objectives can mean there is no hypothesis to prove or disprove and therefore no proper basis for manipulative research.

3 *Reserve objectives must fit into a planning and management hierarchy.*

A set of management objectives for a particular national park or nature reserve cannot exist in isolation. On the one hand they must clearly flow from, or be based upon, the broad long-term conservation, recreation and protection goals of the community and the agency. On the other hand they must be sufficiently relevant to the real world to be capable of development into the budget strategies, works programs and job prescriptions used by field staff.

Western Australia is fortunate in having a well defined planning hierarchy in this area. It starts with our legislation, and the principles set down in the State Conservation Strategy and flows on to the Department's Corporate Plan and thence via Regional, Area and Issue Plans to annual budgets and works programs. At each stage an effort is made to ensure that objectives mesh in with each other, both up and down the hierarchy.

This process provides continuity and consistency of approach, and ensures that everything finally done on the ground is a consequence of policies agreed to at the highest level by the different elements of the community, and disciplines within the Department.

4 *Objectives must be measurable*

It is very important that conservation managers have the means to gauge and to report on the success of their work. This is good for internal morale, and also represents a form of accountability for funds spent. More importantly, the actual measurement of progress is the only way to monitor the real consequences of management action (or inaction!). Efficient biological, social and financial monitoring and control systems are absolutely essential in conservation management. Each of these systems can only work effectively if in the first place management objectives have been expressed in terms which can be quantified in some way.

I recognise that some objectives are almost impossible to express in a form which can be measured or put into a time frame which has any meaning. In this case objectives ("ends") must be broken down into strategies ("means") and the latter put in such a way that results over a specified time can be assessed in a quantitative form.

5 *Objectives must be ranked in order of priority.*

Since there is so much to do, so few resources to apply, and so complex and poorly-understood a system to manage, priorities must be stated. Moreover, priorities in a particular reserve need to reflect the priorities of the agency as a whole.

This is an extremely difficult principle to observe. There are powerful external influences which can over-ride professional opinion; there are historical commitments which cannot be dismissed; and there are personal interests and prejudices amongst managers, rangers and even scientific staff which have the resilience of granite.

Policy-makers within the Department of Conservation and Land Management (CALM) have grappled for nearly two years with the problem of setting priorities amongst the Department's multitude of responsibilities. As an interim measure we have finally adopted an approach of defining "trends" (ie functions or services to be favoured over time, held steady or disfavoured). Hopefully, this will provide managers in the field with the necessary guidance to enable them to rank priorities for resource allocation and research in parks and reserves.

6 *Objectives must take into account the social context of the reserve.*

All reserves have neighbours. And irrespective of their international biological or scenic significance, all are also part of a local community of people. Reserve neighbours and local communities need to be considered and "managed" just as carefully as a reserve itself. If their special interests are ignored they can become a serious threat to the reserve and to the agency. This threat is manifested across the spectrum from political strife to incendiarism, rubbish dumping and shooting. On the other hand, if neighbours and local communities are considered fairly and managers interact properly with them, they can be a wonderful asset and a powerful, constructive and positive force in conservation management. Good neighbours can provide complementary fire, drainage and feral animal and weed control programs and can assist with rehabilitation, interpretation, research and general patrolling.

All reserves also have visitors and it is essential that they be considered in the planning process.

Objectives for reserve management must therefore be outward as well as inward-looking. They must ensure that people living near or visiting the area become involved, have adequate opportunity to debate the issues, learn about the values of the area and understand the ethic underlying plans and works programs. In the case where the traditional Aboriginal owners of the reserves are either present on the reserve, or accessible, the appropriate mechanisms for their involvement must be put in place.

Unless the interests of visitors and local people are taken into account, the most sophisticated ecological management plan in the world may come to nought. But if these people are regarded as legitimate and important stakeholders in the processes of reserve planning and management they can be a key factor in the achievement of conservation objectives.

7 *Objectives must incorporate a "feedback loop".*

Research results, new technology, monitoring plots, or operational experience must all be employed by the manager to indicate whether or not the plan is working. If it is not, or if it can be improved, a restatement of objectives may be required. This process must be foreshadowed from the very beginning.

8 *Objectives must be written down, and expressed in simple, clear language, and in positive terms.*

This is a very general principle, one to be applied across the board in management plans for conservation reserves. Those people who must really understand and become committed to management objectives are often those with the poorest grasp of scientific or agency jargon. Wherever possible we should write for them, not for the "converted" within the Department or a particular scientific discipline.

A positive outlook is very important. "Goals" expressed only in the negative have a discouraging effect on staff and can lead the public to think of conservation management as exclusive. Pessimism can develop into a self-fulfilling prophecy.

This plea for a positive approach should not be taken to mean that I advocate a "do anything for the sake of doing something" philosophy. In fact, an aim to "do nothing" is a perfectly acceptable one for some reserves in some circumstances.

Setting Objectives in Practice : Three Case Studies

I will conclude this paper by examining the objectives set for three Western Australian conservation reserves in the light of these eight principles. The reserves are:

1 Kalbarri, a large (290 000 ha) national park in the sandplains on the mid-west coast. Kalbarri has no formal published management plan. Operations are based upon a set of Interim Management Guidelines that are designed to protect the park from adverse influences until a proper management plan can be prepared. The duration of the Guidelines may be ten years, depending

on other planning priorities, so the objectives they contain will be used as the basis for a great deal of work in the park.

Appendix I is an extract from draft Interim Management Guidelines for Kalbarri National Park and lists the general management aims and the fire protection objectives to be adopted for the park. (Note: the draft guidelines were rewritten in 1988).

2 Nature reserves in the Shires of York and Northam are a group of six small (all less than 460 ha) woodland reserves interspersed among agricultural land in the western wheatbelt. A management plan for the group of reserves was completed and published in early 1987.

Appendix II is an extract from the plan and lists the six general management objectives adopted for these areas.

3 Shannon/D'Entrecasteaux National Park is an extensive (171 500 ha) area on the south coast, encompassing beautiful virgin stands of wet sclerophyll eucalypt forest, coastal heath, wetlands and woodlands. A management plan for the area has recently been published.

Appendix III is an extract from the plan, and lists the general objectives of management and the specific objectives relating to fire protection for the parks.

Table 1 is my assessment of how well these sets of objectives match up to the eight principles discussed above.

TABLE 1
Assessment of plans against principles : 3 case studies

Principle	Kalbarri NP	Nature Reserves of Shires of Northam and York	Shannon D'Entrecasteaux National Park
1. Objectives reflect purpose	Yes	Yes	Yes
2. Objectives reflect eco-systems being managed	Not clearly	Not specifically	Partly
3. Objectives fit into the planning hierarchy	Yes	Yes	Yes
4. Objectives are measurable	Partly	Not clearly	Not clearly
5. Objectives are ranked	No	No	Yes
6. Objectives recognise reserve social context	Yes	Yes	Yes
7. Objectives incorporate a feedback loop	No	Yes	Not explicitly
8. Objectives are written, are simple and are positive	Yes	Yes	Yes

This analysis indicates that the objectives prepared for each of these reserves are generally quite good, but can be improved. The authors of the plans might argue with my interpretation, but I would reply that well stated objectives should not leave room for misinterpretation!

CONCLUSIONS

A well-considered, well-argued and well-written statement of objectives must be the first step in management planning for conservation reserves. There is a lot of management plan writing going on at the moment, especially in Western Australia. It is therefore useful to have a set of principles to provide a guide and a checklist for planning and operational staff.

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ENDNOTE

In this paper I have tried to conform with the following definitions:

a goal: a long term desirable situation

an objective: a clear statement of a result to be achieved within a stated time frame, and oriented to a goal

a strategy: a means by which an objective may be met

Appendix I
Extract From Draft Interim Management Guidelines For Kalbarri National Park

2.0 GENERAL MANAGEMENT OBJECTIVES

- To protect and conserve the scenery, flora, fauna and historic archaeological sites from disfigurement, damage or destruction.

- To provide and maintain facilities for the enjoyment of the natural resources of the Park by the public.

- To provide suitable access within the Park for visitors, and for implementation of management operations.

3.0 FIRE PROTECTION

3.1 **Introduction**

Records show that since 1977, approximately 50 per cent of the Park has been burnt by wildfires. These fires have been caused by lightning, careless campers; escapes from burning off operations on private properties adjoining the Park; and escapes from the Kalbarri rubbish tip. The fire history between 1978 and 1987 is shown on Map 1 in the Appendix.

3.2 **Fire Protection Objectives**

The six main objectives in order of priority are:

- To protect human lives (visitors, neighbours and departmental staff) from wildfire entering or burning within the Park.

- To protect property of neighbouring landholders and Park facilities from damage by uncontrolled wildfires.

- To protect flora, fauna and landscape values from severe damage by uncontrolled fires or from inappropriate burning regimes for suppression techniques.

- To confine fires to predetermined block boundaries so that no more than ten per cent of total Park area is burnt in any single fire event.

- To reduce the risk and frequency of wildfires starting within or near the Park resulting from human activity.

- To retain as much as possible of the Park unburned during the period of this plan.

Appendix II
Extract From Management Plan For Nature Reserves In The Shires Of Northam And York

8. GENERAL MANAGEMENT OBJECTIVES

Management of the six nature reserves covered by this plan will be directed towards the enhancement and maintenance of their collective and individual nature conservation values. This general objective will be achieved by a consideration of the following strategies: protection from fire, pests and dieback; rehabilitation of degraded areas; management of public use; and research and monitoring.

The determination of each strategy has been based on one or more specific objectives -

For protection from fire: to protect human life; to protect the natural values of nature reserves as well as the assets of reserve neighbours; to minimise the risk of wildfires on nature reserves; and to suppress any wildfires that occur.

For protection from pests: to protect the reserve and surrounding farmlands from damage by plant and animal pests.

For protection from dieback: to prevent the spread of dieback into uninfected areas; and to minimise its spread in infected areas.

For rehabilitation of degraded areas: to rehabilitate degraded areas; and to minimise further disturbance.

For management of public use: to encourage an appreciation of the nature conservation values of the York-Northam nature reserves.

For research and monitoring: to encourage use of nature reserves for research, by both amateurs and professionals; and to implement monitoring programs to provide data on the effects of management actions.

Strategies specific to a particular nature reserve are given in the Plan for Management for the individual reserve. General management strategies are given at the end of this plan (Part 8).

Appendix III
Extract From Management Plan For
The Shannon Park And The D'Entrecasteaux National Park

2.0 MANAGEMENT OBJECTIVES FOR THE SHANNON PARK AND D'ENTRECASTEAUX NATIONAL PARK

Management objectives specific to the two Parks were derived from: the above general objectives; the dual purpose of "national park and water"; and the information provided in B. Description of the Parks. The following background information is most relevant to the determination of specific objectives -

- The Shannon Park contains the most protected watershed in the State's south-west and the largest contigous area of karri forest reserved for conservation.
- The four main rivers (Donnelly, Warren, Gardner and Shannon), plus other minor rivers and streams which flow through the Parks, are of great conservation and recreation value. In addition, between them they have an estimated potential yield for water supply of 680 million cubic metres per annum. This yield represents 45 per cent of the divertible potable water resources that remain undeveloped in the south-west region.
- The D'Entrecasteaux National Park contains the only major coastal wetland and dune area reserved for conservation in the south-west.
- Several areas contain important biological and physical features.
- Some areas have been disturbed by human activities and this disturbance is likely to spread unless the areas are actively managed and rehabilitated.
- Many areas in the Parks are capable of sustaining very little public use without irreparable environmental damage.
- There is demand for a variety of recreational opportunities within the Parks, some of which cannot be satisfied elsewhere in the region.
- There are few developed opportunities for recreation in the Parks, especially for people without four-wheel-drive vehicles.
- Our knowledge and understanding of the natural environment, cultural heritage, and existing and future recreational use of the Parks is very limited.

The specific management objectives for the Park are to:

1 Protect the biological and physical environment and the cultural and scientific features of the Parks.

2 Protect and preserve the surface waters and groundwaters of the Park, in terms of both quantity and quality.

3 Rehabilitate the natural environment as necessary.

4 Develop and maintain a basis of knowledge about the biological and physical environment of the Parks, and pass on this information to the public.

5 Provide opportunities for public education regarding the Parks.

6 Provide opportunities for appropriate public recreation, while at the same time ensuring that the environment is capable of supporting the use without unacceptable damage, and that the recreational experiences of visitors are not impaired by conflicting uses.

7 Protect the lives of neighbours and visitors to the Parks.

MINIMUM REQUIREMENTS FOR THE PREPARATION OF FIRE MANAGEMENT PLANS FOR NATURE CONSERVATION LANDS

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SUMMARY

Fire management plans are an important, if not essential device to provide guidance to and establish management practices for the estate manager. In new conservation areas or areas with a limited data base such plans are even more needed than on areas with well established practices. Conservation authorities can access sufficient data and expertise to prepare fire management plans even in the absence of detailed information specific to a conservation area. Experienced fire managers and researchers can extrapolate their knowledge of other areas sufficiently to set standards for most biogeographic regions and provide competent advice to the estate manager.

INTRODUCTION

This paper is not intended as a prescriptive treatise, but rather as a consideration of the reasons for fire management planning and an attempt to arrive at those minimum requirements from which the end user, the estate manager in the field, can derive guidance and comfort.

There can be little doubt there is a need for fire management plans:

(a) to structure planning for the purposes of funding;

(b) for resource allocation including equipment and manpower;

(c) to establish administrative guidelines including approvals and authorities;

(d) in order that the land manager can be secure in operating within a defined ambit and is assured of organisational support within that ambit;

(e) to ensure that the land manager, on behalf of the organisation, meets his legislative responsibilities under fire control legislation appropriate to the State, other land management legislation, and the conservation legislation of the parent body;

(f) to indicate the desired action for land management staff with regard to fire; and

(g) to ensure that the available knowledge base is utilised within the estate in the management of fire.

It is important to understand for whom the plan is designed. Fire management plans are action plans and should be directed at staff on the ground within the estate; in most cases the park manager. Although the organisation has a requirement to have such plans in place, the action officer is a different class of manager from corporate managers within an organisation. Accordingly, fire plans must be pragmatic and realistic, and relate to the actions desired rather than just a consideration of the options. These objectives are determined by the organisation in line with corporate goals.

The purpose of a fire management plan is to prescribe actions specific to the fire problems in that particular land management area. Fire management plans could be incorporated within plans of management. Management plans, however, are statutory documents prepared pursuant to legislation, and are consequently less amenable to frequent change. Such documents define the goals and objectives of a particular management area, and the organisations intent with regard to fire management within that area. A fire management plan, by contrast, needs to be a dynamic document containing detail specific to the circumstances of the place, the season and the resources available at the time. It is therefore better to have the fire management plan as a stand-alone document.

With the evolution of conservation organisations, fire management planning within those organisations no longer relates purely to parks and reserves. Increasingly it is applied to areas under alternative forms of tenure, management arrangements and resources and relates to land not under the direct management of the organisation.

CURRENT SITUATION

Fire management outside urban areas has traditionally been the responsibility of land owners. In the past there have been two major organisational entities actively involved in fire management.

The "Bushfire Control Organisations" have had the objective of co-ordinating and enhancing the individual efforts of land owners, both on their own land and across districts. Their resources have been basically private and provided through volunteers acting as individuals, but aiming to liaise in some co-ordinated manner. The success of this approach throughout Australia has been quite remarkable.

The other main landowners with an active interest in fire management have been the "forestry organisations" whose significant blocks of public land have placed on them responsibilities to meet the objectives required of them; viz to protect the commercial values of public forest lands. As community expectations of the land use on those public lands has changed and developed, the forestry objectives have moved from purely commercial considerations to more ecologically directed considerations. The bulk of fire research in Australia has been carried out on these lands and this long history of research and development has provided the current information and methodology base used throughout the community.

Until recently park authorities did not particularly promote themselves as fire management entities. While there have been some remarkable exceptions (eg the Kosciusko Park), many National Park areas were considered by both the authorities and society as being an overall responsibility of the community rather than of the management authority. Unlike forestry lands there has been a background of confusion and a less clear understanding of the objectives for the land and its resources for society, it being often described as "for the use and enjoyment of the public".

It has taken the information explosion of the last fifteen years to put conservation management authorities in a position where they have been able to more clearly define management objectives for their estate and undertake management in accordance with those objectives. During this time the nature of the conservation estate also has changed. There is now less emphasis on providing ancillary facilities for cities and more on areas dedicated to the protection and management of representative examples of our natural history.

Within the conservation estate the approach also has changed away from the concept of a living museum towards more active management of identified species, communities and systems, and as a result management prescriptions have become more specific to real objectives. Many of these changes have taken place relatively recently. Management authorities now control a mix of parks which are well established and on which the management and use patterns have been cast, and an increasing number of newer parks and management units with no real established management practice or data base. It should be recognised that, particularly on the older more established parks, the intuitive ability of past managers has generally led to sensible practices which have at least maintained these parks, if not enhanced them.

For the conservation management authority an additional factor is the climatic and geographic variation across the State. Consequently, the policy guidelines and objectives for one area of the estate need not necessarily be applicable to other areas (eg southern Western Australia compared with northern and inland Western Australia).

OBJECTIVES

The conservation authority should seek to set the fire management objectives for each individual area consistent with the plan of management for the area. With the increase in biological knowledge of species and communities, it becomes possible to start setting objectives for fire management aimed at sustaining habitat, communities and ecosystems. This then leads to drafting of prescriptions, zoning parts of the estate for intensive management, and monitoring the effectiveness with which the organisation achieves its stated objectives.

It is inevitable that, in the early stages, habitat definition may be coarse or may even be incorrect. However, with monitoring of more intensively managed areas, such oversights and omissions can be identified and prescriptions refined, without incurring an excessive risk to the target species. It should also be recognised that habitat description and definition is a relatively slow process. Studies tend to be based on individual species biology and as such are not holistic, and thus not necessarily integrated with total ecosystem management. As a result of such uncertainty, managers tend to prescribe a variety of treatments as a device to keep options open.

When a conservation agency takes over management of an area there is an expectation that management of that area will, in some manner, be improved. The community, and particularly other land owners in the area, judge our performance on those aspects of management with which they are familiar. In rural Australia fire management is an area in which most established land owners have some experience and some opinion. New personnel with little fire management experience tend to be vociferous in their opinions.

In a new conservation area probably the earliest objective for that area is to meet the legislative obligations as a landholder and to satisfy obligations to neighbouring landholders; in particular, to stop fire emerging from the conservation estate onto other lands and to control fires which enter the estate.

The second objective, again imposed by the community, is the agency's obligation as a landholder to protect life and property. This obligation can become a major preoccupation for the manager on site, particularly in the more extensive parks. As an example, the responsibility of the manager to maintain and protect several hundred kilometres of fenceline is a significant drain on resources and tends not to be recognised within the structure and objectives set by the organisation.

The third objective is to protect those features for which the park is declared or management responsibility undertaken. This requires the identification of unique aspects of the area which need special treatment or protection, and at the least, to maintain those features. A subsidiary objective may be to manipulate, rehabilitate or enhance the ecosystems and habitat to ensure the conservation of the unique features of the area.

The fourth objective which can constrain freedom of action, is to manage the area according to the expectations of the public as users of the park. Public expectations usually do not include burnt areas as a part of the landscape. As a result, managers must go to some lengths to ensure that walking paths etc traverse unburnt examples of the ecosystems on display, and also maintain a high level of interpretive education, both to explain and to justify management activity with regard to fire. The second part of the public use aspect is that the public themselves are a source of ignition and potential damage to the estate.

The Minimum Requirements

Given that the fire management plan is the action plan for the manager in the field, and given that in much of the estate staffing, funding and equipment are not well resourced, it is suggested that the following are the minima.

1 Authority

A policy statement from the conservation organisation that empowers the manager to act within a defined ambit and allows him to make decisions on action, the commitment of funds and resources, and the control of other peoples' activities within that ambit.

2 Objectives

The organisation needs to provide a statement of the objectives for the estate and the implications with regard to fire management.

3 Fire Action Guidelines

This stems from the statement of objectives and covers the organisations' intent in meeting those objectives; eg whether all fires should be controlled; whether only legal obligations should be met and whether there is sufficient information; establishing priorities for the assets of the estate such as vulnerable communities or species; and defining the special effort required in their management.

4 Resources

The manager then requires a listing of his resources in the area, the region and external to the organisation, and the translation of these resources into phone numbers and addresses, duty rosters etc.

5 Management Cycles

This is basically a seasonal cycle of performance requirements, such as fire break locations, management burning areas and priorities with regard to protection.

6 External Influences

The management cycle must take into account other imposing factors, such as the local burning patterns within the district. In the more remote areas this could still be the late season fire that is allowed to burn through the district or, as in an increasing number of cases, the fire use and patterns of occurrence established by Aboriginal occupants of the area.

7 Obligatory Requirements

Compulsory requirements such as legislation, including requirements at the shire level, the need for permits, advice to neighbours and so on, should be detailed.

8 Standards

Depending on the quality of the data base, an agreed set of standards with regard to fire use should be set. These can be quite simplistic in the absence of a good data base; eg in savannah an interim standard based on a maximum flame height for management burns, recommended season of burns, time of day and so on. These standards can be fairly easily produced over most vegetation types by an experienced fire manager.

9 Basic Data

The basic climatic data for an area is usually readily available. The important factors are temperature, rainfall, humidity and wind patterns. Added to this some record of basic fuel characteristics is required, which in an unknown area may be as simple as "grass" or "litter" together with observed characteristics.

10 Mapping

Maps showing access, assets to be protected, vegetation types, and areas requiring specific response are a basic requirement in the new park; these may initially be no more than hand drawn "mud maps".

All of the above data sets can be provided in the absence of more detailed information specific to that estate.

In this section I have attempted to demonstrate the level of simplicity needed to establish fire management. With increased input to the data base the effectiveness of the plan can be upgraded. However, the action plan must remain at a simple level based on the practical requirements of the park manager. A manager faced with a fire problem does not have the time or the inclination to read the basis for his recommended actions.

Improving on the Minimum

In order to upgrade fire management, it is necessary to develop an understanding and a data base relating to the effects of various fire regimes on communities and habitat, and through a knowledge of fire behaviour, determine how these effects can be manipulated to maintain or rehabilitate communities and habitat. The two areas of fire effects and fire behaviour have been the subject of considerable research in various communities and methodologies are developing which relate those findings to management practice.

In assessing the natural characteristics of the estate the first phase of management is logically to seek to maintain the status quo. This relies on an understanding of the systems that have been inherited in the estate and of the fire patterns which have operated on that system. A large amount of this phase relates to observation of the existing system. It would be reasonable to state that for most biogeographic regions, experience from elsewhere can be extrapolated with regard to the type of fire behaviour that will, if nothing else, maintain the status quo rather than allow further degradation.

The second phase of management would be to seek to set directions for management to encourage diversity of communities within systems, enhance their structural development and floristic richness. This issue depends very strongly on the objectives set for the estate, whether for single species or for multiple species within communities. In general, management directed to individual species would take place at a more sophisticated level of management where the phase one and phase two management strategies have been successfully put in place.

Within nature conservation lands the long-term objecive should be not simply that of protecting a resource, but of managing the biological entities that make up that resource. The question thus arises - how do we translate a research effort into a management prescription, specific to a park area? There are a number of ways of achieving this.

The organisation must be active in spreading its research personnel to establish personal contact with individual park managers, for the benefit of that park. As previously stated, much of the basic data required can be provided "off the top of the head" by an experienced fire manager. In the long run an active research program within the park is the most positive method of transferring knowledge into management practice. Given the limited research resources within any organisation, the more remote areas will continue to suffer. The park manager can, however, improve his data base by maintaining fire records, establishing monitoring plots and by intelligent observation. The organisation through its researchers should seek to advise and educate the manager so that his "ad-hoc" information can be effectively integrated into practice.

In a new park, the managers preoccupations are at a more pragmatic level than a fully resourced and developed park. His ability to apply more intensive and sophisticated methodology is usually constrained. The organisation therefore can satisfy the needs for management planning on an area with a limited data base by arranging for visits by researchers, and the transmission of their experience to the park at a reconnaissance level of observations until the second phase of enhanced management evolves. Other speakers will touch on methodology such as "the expert system" whereby the transmission of this data is formalised.

CONCLUSION

This paper has attempted to define the ambit of a minimal data set. I have attempted to demonstrate that there is sufficient in-house knowledge in each State authority to create a minimal data set. For the benefit of the organisation and for the benefit of the manager of each area of the estate, a fire management plan is necessary to both demonstrate and guide management.

I have attempted to separate the fire management plan, which is an action plan, from the plan of management which is a document purporting to set management procedures for a significant period. I have also attempted to establish a basis from which professional planners and researchers can build on the local knowledge developed by the estate manager.

And finally I have attempted to indicate that even with a poor data base there is sufficient information readily available to establish fire management planning, and in fact, it is under such circumstances that a fire management plan is most needed.

THE MINIMUM DATA SET AND INFORMATION NECESSARY FOR THE PREPARATION OF FIRE MANAGEMENT PLANS FOR NATIONAL PARKS AND CONSERVATION RESERVES

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SUMMARY

The approaches to fire management planning in national parks and conservation reserves have and are changing at the present time as the role of fire as a process in the conservation of our native biota is increasingly understood and appreciated. The change from a simplistic and at times inflexible fire management approach to scientifically based programs including planned burning regimes has been made possible by the development of predictive models which can integrate and manipulate detailed and very large data bases compiled for national parks and conservation reserves.

These data are foremost biogeographical, but individually they provide only limited input into the development of a fire management plan. An information set must be drawn from the integration of these data bases through modelling and overlay techniques. The minimum information set is that of fire behaviour prediction and the associated hazard and risk analysis, such that values at risk can be identified in terms of the extent, degree, frequency and regularity of potential impact.

Only when the above minimum data and information sets are compiled and generated on an holistic basis for a park or reserve, can sound and professional fire management plans be prepared.

INTRODUCTION

The science of fire management has a background of very conservative attitudes where changes in concepts and practices have occurred very slowly. This slow change has provided the opportunity for the development of entrenched concepts and ideas on fire management to the extent that many of the principles and practices of fire management today have little or no basis except that of experience and time. This is no more evident than with prescribed burning, now commonly referred to as hazard reduction burning or protection burning. The principles and concepts for such burning were developed in the 1950s, and little in the way of applications research has been undertaken since that time with respect to specific vegetation types or communities.

Prescribed burning has over the years been the core of all fire management plans and in some well documented plans is the only program. Fire management plans which are based on such a single objective program may be adequate for some commercial forestry and vacant crown lands, but are far too simplistic for implementation in natural areas set aside for conservation of the natural biota. The integration of conservation objectives with fire management objectives makes planning far more complex than that in other areas. To address the complexity of issues, managers must have available to them relevant detailed data on the natural resources which contribute to fire occurrence and behaviour, and the resources of value which may potentially be affected by a fire event.

Data Bases

Fuel

With the wide acceptance of prescribed burning for the reduction of combustible fuel in natural lands, and the consequent reduction in potential maximum intensities of a wildfire event occurring subsequent to a prescribed fire, a widespread belief has evolved which infers that all forest, shrub and grass land fuels over a perceived level pose fire hazards. It is undisputed that increasing fuel loads provide increasing fire intensities under a given set of weather parameters. However, similar fuel loads in different vegetation types may not have the same flammability, and hence potential, to generate similar fire intensities.

Where prescribed burning for fuel reduction is the major component of any fire management plan it is to be recognised that not all the vegetation types of a reserve may contribute to hazardous fuel levels or hazard fire situations. It is obvious that where such a perception is held a detailed knowledge of the fuel complexes of a reserve is essential to assist planning and to develop prescriptions for the weather conditions under which burning is carried out. The objectives of any planned burning, such as proportion of area to be burnt and the proportion of fuel to be removed, also need to be known.

The acceptance that fine litter fuels in excess of ten tonnes per hectare are a hazard makes two inaccurate assumptions. The first is that only the fine fuels contribute to the perceived fire hazard, and the second is the actual concept of hazard. To assess the potential contribution of fuels to a fire hazard situation all parameters which make up the fuel complex must therefore be considered.

Table 1
Components Of Fuel Complex

- Litter fall rate (tonnes per hectare per year)
- Proportion of litter in total fine fuel
- Proportion of grass and herbs in total fine fuel
- Proportion of 6 mm material in total fine fuel
- Proportion of shrub foliage in total fine fuel
- Proportion of shrub branchwood in total fine fuel
- Percentage cover of various strata
- Packing ratios of various strata
- Weight of dead material >6 mm and <25 mm
- Weight of dead material >25 mm and <75 mm
- Weight of dead material >75 mm

Terrain Features

Slope and Aspect

Slope has long been recognised as a major natural terrain element which makes a significant contribution to fire behaviour, its influence increasing with length of slope and steepness. The orientation of the slope to prevailing fire weather conditions controls the potential maximum influence slope has on fire behaviour, with the worst situation being the strongest winds prevailing directly up the steepest slope.

To accurately predict the potential maximum fire behaviour in terms of rate of spread (ROS) and intensity, the slopes must be defined within small slope class ranges. Such detail is readily acquired from the digitising of available topographic maps and aerial photographs. Aspect data can similarly be acquired from the above digitising and the minimum slope and aspect data set should be slope classes to five degrees extrapolated from twenty metre contours and integrated with eight aspect classes.

These combinations of slope and aspect are the minimum for reasonably accurate fire prediction, but more detail may be required in extremely dissected terrain such as in the Blue Mountains west of Sydney. The digitised data should ideally be extracted from the smallest contour interval available on the largest scale maps.

Topography

The influence of slope and aspect on fire behaviour is only predictable when other topographic features do not influence the prevailing wind conditions. In terrain which is very dissected winds are vectored and unexpected wind eddies and wind directions can occur during a fire event. Predicting these unexpected wind conditions is extremely difficult as they are a result of micro-scale topographic features. The more detailed the slope and aspect data the greater is the amelioration of the unexpected fire weather features. Detailed slope and aspect data integrated with elevation data also enable a topographic moisture sequence to be generated with respect to fuel moisture and vegetation.

Vegetation

In many fire management programs in the past it is evident that very simplistic vegetation data has been an input to fire prediction and the planning of fire management strategies. As prescribed burning has dominated fire management, forest and grassland fuels have been the major biological factor and input. With respect to fire the latter will continue in the future but it is to be recognised that the fuel complex is a function of the vegetation type, the species of the vegetation complex, the prevailing weather conditions and terrain. Too much acceptance has been made of the simple concept that Australian sclerophyllous vegetation contributes similar components, in similar time frames to the fuel complex of a forest. To determine or predict the fuel loads existing in forest, woodland, shrubland, or grassland, vegetation must firstly be classified and mapped as basic data. The vegetation formation classes must be further detailed by species association and structural types. For each species association a maximum potential fuel load can be calculated and fuel accumulation rates generated using terrain data as it affects the topographic moisture sequence.

Structural vegetation data are also necessary to provide for prediction of fire behaviour as both live and standing components of the fuel complex are consumed in a fire. The degree of physical impact or damage to the vegetation by a fire is partly determined by the structure of the vegetation.

The minimum vegetation data for fire prediction therefore are those which enable "fuels" to be determined and the physical impact of fire to be predicted. The actual detail or scale of vegetation data is a factor of the number of vegetation types or associations and their relationships to terrain features. In Morton National Park in New South Wales, for example, 98 vegetation associations occur in an area of approximately 200 000 hectares, but the fuel complexes can be accounted for in 12 fuel accumulation curves. Recognition of all vegetation associations is still required however, as the impacts of fires vary widely in all associations within the expected ranges of fire intensities.

Fire History

Wildfire events have generally been poorly documented in the past, with at best the gross area of a fire being mapped. As vegetation structural and species regeneration rates (and hence fuel accumulation rates) are a response to fire intensities, the latter must be accurately mapped both in the future and where possible for past fire events.

A minimum fire history data set is a record of all wildfire and planned fire events which have occurred within the life cycle of the oldest species of the vegetation. Such a record is required to model the influence of each fire event on the accumulation of fuels in each vegetation association, and to assess the past and potential impact of fire on vegetation trends. The limitations of the minimum fire history data set are obvious, the limitations on modelling only being minimised by the acquisition of very detailed resource data.

Historic Weather Data

Where prediction of fire behaviour is made in the planning of fire management strategies such as prescribed burning, hypothetical or the "prescribed weather conditions" are generally used. In many areas this may suffice as the minimum data set, but for accurate predictions covering large tracts of land such as a national park, the hypothetical weather set is inappropriate for the determination of management strategies.

Historic weather data sets are therefore the minimum required to provide an assessment of the likely potential of a prescribed weather set being met within the season or time frame in which planned burning is proposed. Historic data sets also provide for the generation of accumulative percentile weather conditions which are much more meaningful in selecting the prescribed conditions to implement a prescribed fire to meet prescribed objectives. Percentile weather data sets also provide for the prediction of the potential number of days during a fire season that a design day with respect to wildfire would exceed maximum manageable fire intensities. The latter is a more defined and accurate way of assessing planned or unplanned fire effects and in planning fire suppression strategies.

Table 2
Fire Analysis Using Historic Fire Weather Data
(Kosciusko National Park)

PERCENTILE	RATES OF SPREAD (M/MIN)			BYRAM'S INTENSITY (KCAL/M/SEC)		
	DOWN SLOPE	ACROSS SLOPE	UP SLOPE	DOWN SLOPE	ACROSS SLOPE	UP SLOPE
1	.0	.0	.0	0.	0.	0.
5	.0	.0	.0	0.	0.	0.
10	.0	.0	.0	0.	0.	0.
15	.0	.0	.0	0.	0.	0.
20	.0	.0	.0	0.	0.	0.
25	.0	.0	.0	0.	0.	0.
30	.0	.0	.0	18.	2.	63.
35	.1	.0	.2	23.	3.	85.
40	.2	.0	.5	31.	3.	116.
45	.4	.0	1.0	33.	4.	124.
50	.6	.1	1.8	66.	8.	254.
55	1.0	.1	3.0	112.	14.	436.
60	1.3	.1	4.0	116.	14.	455.
65	1.8	.1	5.6	120.	15.	472.
70	2.0	.2	6.4	131.	16.	514.
75	2.2	.2	7.0	142.	17.	557.
80	2.4	.2	7.6	154.	18.	603.
85	2.7	.3	8.5	166.	19.	649.
90	2.9	.3	9.3	190.	20.	735.
95	3.2	.4	10.2	218.	22.	834.
99	3.7	.4	11.7	253.	24.	962.
				357.	31.	1335.

Information Bases

Detailed natural resource data bases are essential for accurate prediction of planned and unplanned fire behaviour, these predictions then being used to carry out regional hazard and risk assessment. Hazard and risk assessment is thus the dominant component of fire management planning as it draws upon elements of fire behaviour, impacts on vegetation and the location relative to fire potential of resources of value (viz life, property, cultural, biological and landscape features).

Site Specific Hazard and Risk Assessment

As all land management agencies have statutory obligations to life and property under Bush Fire Acts or equivalent legislation, the assessment and quantification of hazards becomes an essential component in fire management in natural lands, particularly where they adjoin urban and rural/urban areas (eg Blue Mountains, New South Wales; Adelaide Hills, South Australia; Dandenong Ranges, Victoria; Darling Ranges, Western Australia).

Hazards in this context are not singularly identified in terms of fuel loads exceeding a pre-conceived level (viz ten tonnes per hectare), but include the relationship between sites of high intensity fire, the distance from sites or

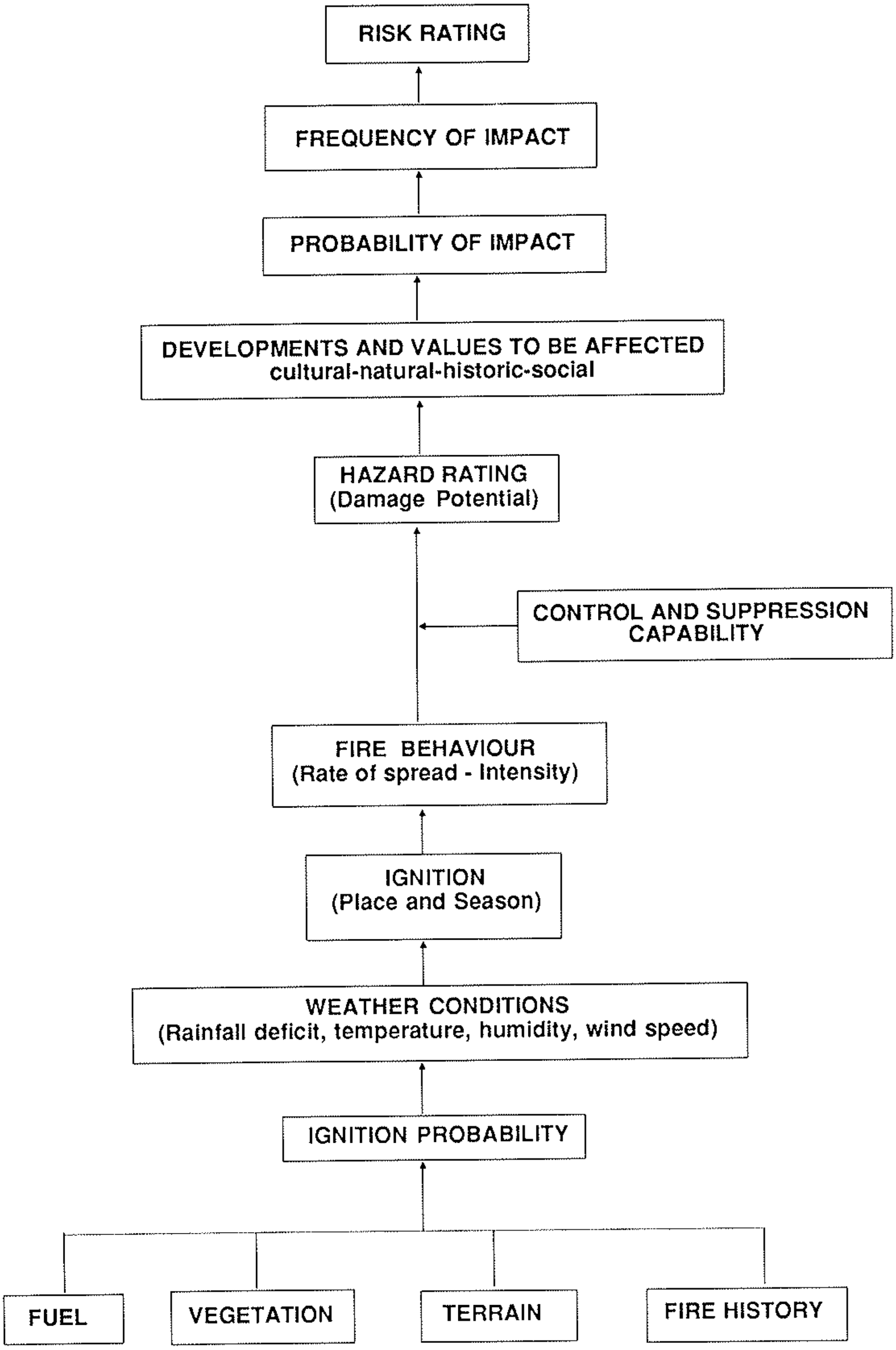

FIGURE I
Hazard And Risk Assessment Process

features of value, the potential rate of spread of a fire and the suppression capability of the land management agency on whose land a fire occurs.

The risk assessment component of the program recognises the economic and biological value of the resources and features which may be impacted by fire. It is to be recognised in fire management planning that in any one fire not all areas of the fire pose the same threat, even though the hazards may be similar. This applies even when the hazard is deemed to be fuel loads exceeding the ten tonnes per hectare level. Risk rating also includes prediction of the potential occurrence of wildfires and the regularity of occurrence at any site.

The determination of whether a fire poses an acceptable or unacceptable risk is of course subjective. Managers must identify the level of risk a development or feature of value can be exposed to and the limits of risk they are prepared to accept as the planning and management authorities (Kessell and Good 1985).

"Hazards" do not exist as static factors but are continually changing as a response to weather, fuel, public expectation and demands on the land and so on. Similarly the hazards change spatially requiring a dynamic approach to hazard and risk assessment to be made through the integration and manipulation of the data bases considered above (Figure 1).

The minimum information from such a program is thus site specific fire behaviour related to features of value and identified by a distance and time component from the fire site(s) to the site of potential impact. A case study of the use of such a program is outlined in the paper by Worboys and Gellie in these proceedings.

Legislation

As noted previously, all bushfire management is constrained by the relevant bushfires legislation in each State, but more recent environmental legislation (eg New South Wales Environmental Planning and Assessment Act), has had a greater influence on the wider program of fire management which encompasses impacts and effects on the environment.

Part V of the New South Wales Act, for example, imposes upon land management agencies the requirement to give detailed consideration to the environmental consequences of any management activity, and in assessing the likely consequences of fire management the following must be taken into account.

"Any activity that may cause:

- any environmental impact on a community
- any environmental impact on the ecosystems of the locality
- a diminution of the aesthetic, recreational, scientific or other environmental quality or value of a locality
- any effect upon a locality, place etc of special value for present and future generations

- any endangering of any species of native biota
- any long-term effects on the environment
- any degradation of the quality of the environment
- any risk to the safety of the environment
- any curtailing of beneficial uses of the environment
- any pollution of the environment
- any cumulative environmental effects."

To address these areas of assessment it is obvious that detailed data as considered above are required to enable an assessment of the significance of any fire management activity as an impact on the environment. It is important to note that an environmental impact statement will not necessarily be required but it does mean that a detailed assessment is carried out as a minimum.

Environmental Legislation and Prescribed Burning

Due to the various concepts of prescribed burning and the many conflicts over such burning in conservation areas, the requirements and obligations of the E.P. and A. Act have been applied more to this activity than any other fire management strategy.

It is contended by some authorities that the Act is an imposition restricting the use and implementation of prescribed burning as a strategy in fire management. It has also been inferred that managers of nature conservation lands use the Act to justify the limited use of prescribed burning in national parks. Taken in the correct context this is true to some degree as the widespread use of prescribed burning for the singular objective of fuel reduction is not now carried out in the national parks in New South Wales (Good 1985).

The E.P. and A. Act has not imposed this restriction but simply reinforced what managers have for some years identified; that hazards and risks are site specific requiring site specific hazard reduction. What the Act has virtually imposed is the need to collate and integrate detailed site data and carry out detailed hazard assessment. The Act has thus contributed to the resolution of conflicts over the use of prescribed burning and has ensured that fire management is now planned on a sound knowledge of the very resources for which conservation reserves have been established to preserve.

Table 3 provides guidelines to the fire management activities likely to have an impact on the environment and to which the requirements of the E.P. and A. Act apply with respect to fire management.

Ecological Data

There is an obvious requirement for an appreciation of a minimum level of ecological data in the preparation of a management plan, but what constitutes a minimum is impossible to define in general terms. The minimum level for any one plan will be that which provides an appreciation of the role of fire in a park for which a plan is being prepared. The ecological role of fire and the responses of native biota to planned and unplanned fire have been documented in many case examples and ecological guidelines must be developed from these. The minimum ecological information may be considered as a detailed knowledge of the general responses of the vegetation complex to a fire regime(s) and the post-fire vegetation/habitat trends.

Social, Economic and Cultural Information

Fire management in national parks is largely constrained by social, cultural and economic issues and not ecological conflicts. Sound fire management planning must therefore be regionally based encompassing rural and urban lands adjoining a park and which are potentially under threat from a fire event in the park.

It is often said that park management is as much a social and economic issue as one of ecological resource management and this is very much the situation in fire management. If managers are not conversant with the "local" bushfire issues the local politics can destroy the best endeavours of ecological fire management in the wider spheres of the park. Leaver, and Worboys and Gellie in their respective papers in these proceedings note in detail this aspect of fire management.

A minimum information base in this context is therefore an appreciation of local attitudes to reserve fire management, an assessment of potential impacts of fires on life and property at the park and urban/rural boundary, and an involvement of the local community in co-operative fire management. The latter would generally only extend to co-operative suppression planning and implementation.

CONCLUSION

The minimum resource data required for sound and professional fire management planning can be readily identified as those which contribute to fire occurrence and behaviour and those which may be affected by fire, including both the native biota and the built environment. The link between the two is achieved through detailed hazard and risk assessment programs; these programs drawing upon both natural resource data bases and social, economic, cultural and legislative information.

The core issue in fire management remains that of prescribed burning and until a more rational and flexible approach is taken to it through the identification and quantification of the specific hazards and risks all other ecologically based fire management objectives will be compromised and never met. Inflexible programs with singular objectives such as prescribed burning for the reduction of perceived hazard levels of fuel are inappropriate in national park management except where hazard and risk assessment identifies sites where obligatory hazard reduction with respect to wildfire intensity exists. On the other hand the general public has been brought up on the concept of prescribed burning as the panacea of protection for life and property, so managers must sell their concepts of fire management including planned burning to the wider community. To achieve this the manager of national parks must acquire and draw upon all available resource data and information, such that complex ecological fire management objectives can be met and not be compromised by obligatory requirements for "protection" of life and property.

Table 3
Fire Suppression And Mitigation Activities To Be Considered In Terms Of The NSW Environmental Planning And Assessment Act

ACTIVITY	NATURE OF ACTIVITY
Wildfire Suppression and Control	Containment using:- Hand tools Earthmoving equipment Aerial or ground based chemical retardents Backburning/burning out * Inactive containment using natural barriers
Mitigation	
- Pre suppression and fuel reduction activities	Aerial and ground based fuel reduction by burning Manual fuel removal and modification Provision of non-fuel areas Modification of the vegetation and fuel complex - planting of other species etc.
Fire Trails	Construction and maintenance of fire trails for:- firebreaks suppression access physical separation of vegetation and features threat of fire occurrence physical barrier to the spread of fire ignition sites
Planning controls	Land use controls and monitoring activities.

* this containment strategy infers a degree of "do nothing approach" which under the EP and A Act is still deemed to be an activity required to be assessed for potential impact.

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Kessell, S.R. and Good, R.B. (1985). Technological advances in bushfire management and planning. In: *Proceedings 9th Invitation Symposium - National Disasters in Australia.* (Ed M.F.R. Mulcahy) pp 323 - 344. Academy of Technological Sciences, Parkville, Victoria.

Appendix I
Basis Of A Fire Management Plan

1. General objectives of fire management
2. Management responsibilities and the statutory context
3. Summary list of park values
4. Vegetation and fuel descriptions
5. Terrain descriptions as they influence vegetation, fuel and fire behaviour
6. Weather data descriptions as they influence fire behaviour and fuel moisture
7. Vegetation and habitat trend objectives
8. Fire effects on the physical and biological environment
9. Fire effects on the social environment
10. Review of fire management techniques
11. Concepts of hazard
12. Management strategies to meet defined objectives and site specific fire regimes
13. Hazard and risk assessment
14. Objectives of planned burning
15. Fire management as an activity under the Environmental Planning and Assessment Act
16. Environmental assessment of fire management

CRITICAL DATA REQUIREMENTS FOR THE EFFECTIVE MANAGEMENT OF FIRE ON NATURE CONSERVATION LANDS IN SOUTH WESTERN AUSTRALIA

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SUMMARY

Decisions relating to the management of fire on nature conservation lands should be based on a sound knowledge of the natural resources of the area and the processes that sustain those resources. Administrative, legal and cultural factors must also be taken into consideration. Critical data requirements correspond directly to the fire management objectives of the reserve and must address four key questions:

1 What are the past, current and likely future regimes of fire in the reserve?

2 How does the biota respond to these regimes?

3 How does fire interact with reserve neighbours and visitors?

4 What activities can be undertaken with the available resources?

In this paper we propose a set of critical data necessary for the effective management of fire on nature conservation lands in south-west Western Australia. A framework is derived that is applicable to all reserves but has the flexibility to cater for the management requirements of individual reserves. Strategies for management in the absence of critical data are also proposed.

INTRODUCTION

Policies and objectives for the management of fire have evolved rapidly in recent years in response to changed land use objectives, improved information and increased public awareness of environmental issues (McCaw and Burrows 1988, Good 1981). Fire management in conservation reserves should be based on a firm understanding of the role of fire in the ecosystem. However, the field of fire ecology is extensive and the resources available to undertake the necessary studies are limited. Additional factors including legal and administrative constraints, and local attitudes to conservation must also be considered in fire management decisions.

Specific objectives for the management of fire should be consistent with the overall management goals for a reserve. Clear statement of these goals in a formal management plan or set of interim guidelines for necessary operations should therefore precede the formulation of specific fire management objectives. Underwood (see p. 27) provides a series of guidelines to assist with the process of objective setting.

Planning for fire management on nature conservation lands must address four key questions:

1 What are the past, current and likely future regimes of fire in the reserve?

2 How does the biota respond to these regimes?

3 How does fire interact with reserve neighbours and visitors?

4 What activities can be undertaken with the available resources?

Critical data that can be considered necessary to answer the first three questions at a level of detail appropriate to a particular reserve at a given time. The fourth question addresses the extent to which critical data can be effectively used for management. This may be a significant factor if the resources available do not adequately reflect the perceived value of a reserve.

Data Requirements

Fire Regimes

The frequency, intensity and seasonality of fire together characterise a fire regime (Gill 1975). The areal extent and shape of individual fires may also be important in determining the rate of recolonisation from adjacent areas and the impact of grazing animals (Grubb and Hopkins 1986). The range of fire regimes within a reserve will be determined by two primary factors:

(a) the opportunity for fire spread, which is dependent on fuel characteristics and weather conditions; and

(b) the risk (Luke and McArthur 1978) or probability of fire ignition.

To adequately define the opportunity for fire spread, fuel, topographic and weather information should be integrated in the form of a fire behaviour model. For planning purposes fire behaviour models should provide unbiased predictions over a wide range of conditions, although a high level of precision may not be required. Fire behaviour models developed in Australia for grasslands (McArthur 1977, Condon 1979) and eucalypt forests (McArthur 1967, Sneeuwjagt and Peet 1985) predict fire behaviour according to basic weather and fuel quantity inputs. Being empirically derived, predictions of fire behaviour from these models are most reliable when fuel conditions are similar to those for which the model was developed. The fire spread model developed by Rothermel (1972) and its derivatives have potential for application in a wide range of fuels but require detailed information about fuel characteristics: considerable field calibration of such models will be required in most circumstances (Catchpole 1987).

Fuel characteristics such as structure, quantity and distribution will be strongly influenced by the nature of the vegetation and the time since previous fire; maps of vegetation type and fire history are therefore critical. Additional information useful in fire behaviour prediction can be obtained from vegetation maps including the impact of canopy height and density on wind strength, potential for crown fires and long distance spotting, and the necessity for mop-up of burning woody debris or peat following fire. Depending on the size and complexity of the data base involved this information may be readily handled by map overlays, or may require computer-based geographic information systems (Kessel and Good 1985).

Adequate fire behaviour guides are not currently available for many fuel types in Western Australia, and even with a substantial committment to ongoing research this situation will prevail for some time to come. However, local experience combined with analysis of historical weather and fire data can provide an adequate basis for examining possible fire regimes in different vegetation types. Daily records of rainfall, maximum temperature, minimum relative humidity and wind speed and direction are available for most settlements and form the basic inputs to several of the fire behaviour models widely used in Australia. Preliminary analysis of this basic information will allow definition of periods when fire spread is unlikely, fires of low to moderate intensity may occur, or when there is a high probability of fires rapidly becoming intense and uncontrollable.

Reserves that generate a high level of interest tend to pose complex issues for management and therefore require comprehensive data on which to base decisions. The increasing level of public interest in the management of fire on conservation lands makes it likely that sophisticated computer systems incorporating geographic and fire behaviour information will become necessary (Kessel and Good 1985).

The second major factor determining fire regimes is the risk, or probability of fire ignition. In the forested areas of south-west Western Australia, human activity is responsible for about 93 per cent of unplanned fires, with lightning accounting for the remaining 7 per cent (Underwood and Christensen 1981). Careful analysis of historical records of unplanned fires is important in quantifying the level of risk. Such records should describe

(a) the cause of the fire (eg lightning, arson, escapes from campfires, industrial operations or prescribed burning);

(b) geographic patterns of fire occurrence;

(c) seasonality of fire ignition; and

(d) the size of the fires.

Analysis of these factors may suggest ways in which the frequency of unplanned fires could be reduced through enforcement of regulations, public education or alteration of activities which entail a high risk of fire. It also enables the provision of an effective detection and suppression system.

Where land use patterns are changing rapidly, historical fire regimes may not necessarily provide a good indication of future fire regimes. For example escapes from high intensity agricultural clearing fires have been a major cause of summer and autumn fires in reserves in the south-west of Western Australia in the last fifty years. However, clearing fires are now infrequent in areas where agriculture is fully developed. Burrows *et al* (1987) reported that the area of Dryandra forest burnt by wildfires declined markedly after 1960, corresponding with the completion of land clearing in the district. Historical changes in fire regimes are important in determining appropriate or perceived necessary regimes in the future.

Response of the Biota to Fire

The response of the biota to fire regimes is a crucial element in making decisions about the use of fire. Although there have been many studies of the effects of a single fire, few studies have been published on the response of the biota to fire regimes. Nevertheless it is possible to make fairly accurate and reliable predictions on the basis of results from studies of single fires when they are coupled with a good knowledge of the life history strategies of the component organisms (Burrows *et al* 1987, Hopkins and Saunders 1987). The three types of information on the biota currently most requested and, when available, most readily applied by reserve managers are:

(a) the identity, location and extent of plant community types and areas rich in fauna;

(b) the identity, location and extent of the habitats and requirements of vulnerable species; and

(c) the identity, location and extent of key taxa and how fire management can ensure their continued role in community organisation.

In this section we examine critical data needs relating to communities, vulnerable species and key taxa and examine the role of monitoring in gathering such data.

Communities

The definition and delineation of plant communities and their correlation with landform/soils maps is an important step in land use planning (Havel 1981). Managers of public land need an objective, explicit basis for determining broadscale management units and for distinguishing the community types within their jurisdiction. Classification schemes must be able to be related to conveniently mapped characteristics if they are to be effective in reserve management.

Maps of landforms based on geomorphological characteristics have proven valuable in studies of land use, (McArthur and Clifton 1975), plant community patterns (Heddle *et al* 1980, Cresswell and Bridgewater 1985, Wardell-Johnson *et al* in press) and as a basis for stratifying samples for survey purposes (McKenzie 1984, Burrows *et al* 1987, Wardell-Johnson *et al* in press). An understanding of the relationships of communities to climatic and edaphic factors enables the definition of similar sites and establishes their extent and distribution within and between reserves. Site specific work can thus be extended beyond initial survey sites thereby placing detailed local studies in a broader regional context.

Scale is an important factor in assessing the usefulness of landform/soils and vegetation mapping; and in the location of areas rich in fauna. A first step for the breakdown of units should be within a broad region eg Churchward and McArthur (1978) and Churchward *et al* (1988). Such studies enable the portrayal of broad scale patterning and the assessment of the adequacy of the reserve system. However, to be valuable in reserve management important reserves within a region should be mapped at finer resolution. Landform soils mapping at 1:25 000 (Churchward personal communication) has proven valuable in management for the conservation of Tammar wallabies (*Macropus eugenii* Desmarest, 1817) in Perup Nature Reserve (Figure 1) by facilitating the prediction of the potential extent of thicket distribution within the reserve.

Areas rich in fauna should be considered at fine scale within the reserve system and have been related to nutrient distribution in NSW (Braithwaite 1983). Nutrient rich areas could be mapped from vegetation types. If the agents governing the pattern of distribution are known, further areas can be determined, suitable sites artificially created and translocation programmes carried out.

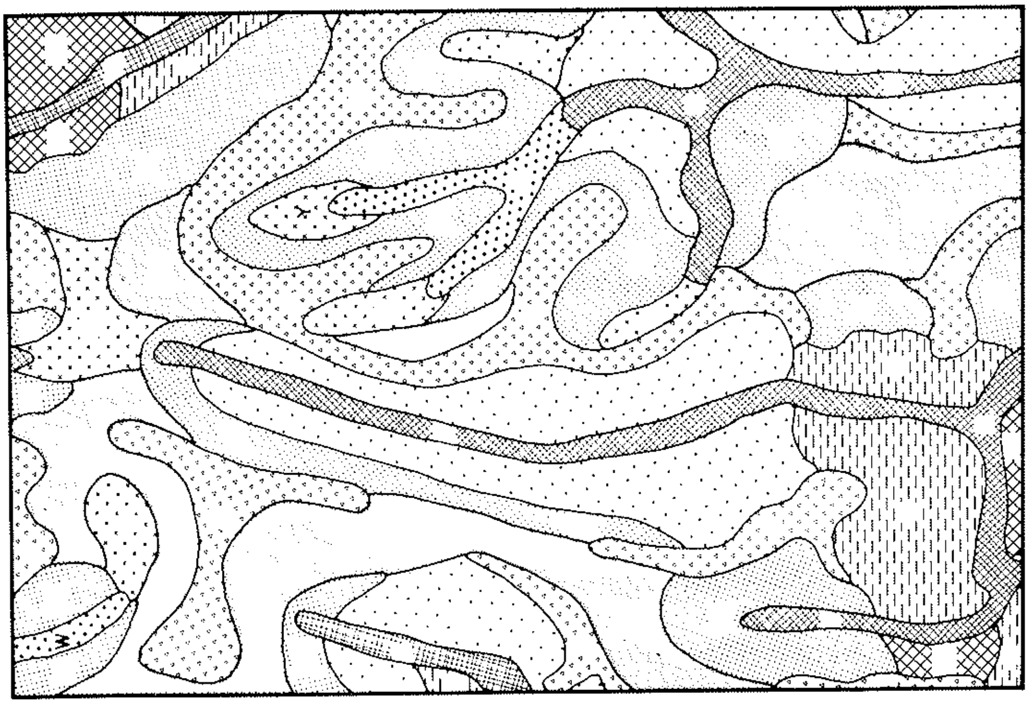
Vulnerable Species

Vulnerable plant species are defined as those species whose populations can be reduced or eliminated by inappropriate management regimes. These species may have low ecological tolerances (Austin and Belbin 1982) or regenerative characteristics (Gill 1981) that are dependent on particular disturbance regimes. Species that are susceptible to disease wherever they occur, should be considered vulnerable.

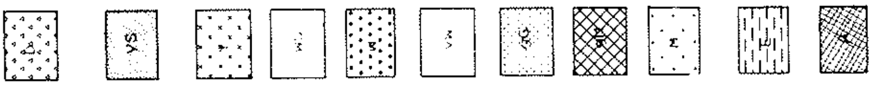
The identification and mapping of vulnerable species is necessary if we are to be successful in managing for the continued maintenance of their populations at a local level. Because of the high rate of endemism (Hopper 1979) many of the species in the south-west are likely to be vulnerable. Such species may be rare or restricted, and where vulnerable, are often at the edge of their ecological range. Rarity in itself, however, is not the major consideration in the conservation of vulnerable species. For the purposes of fire management planning the distributions of vulnerable species and their regenerative characteristics need to be determined so that operations can be designed accordingly.

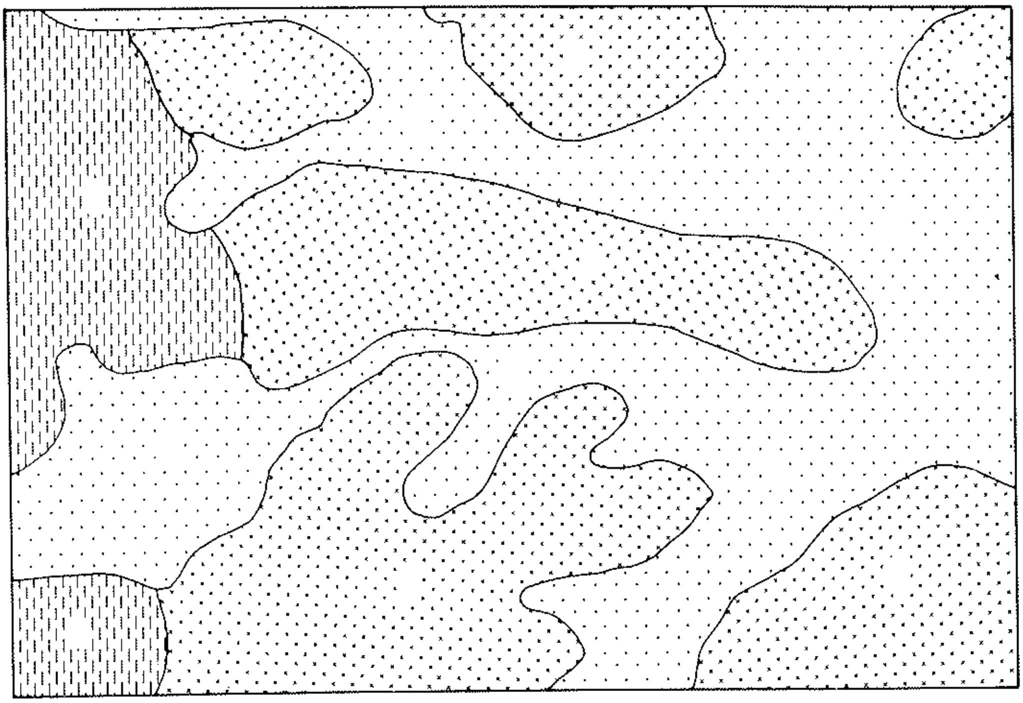
Many fire sensitive obligate seed regenerators are regarded as vulnerable (Plate 1). The primary juvenile period or age to reproductive maturity is important for the conservation of these species (Gill and McMahon 1986). Many species with fleshy underground storage organs may be vulnerable to fire during their flowering period when most of the plants resources are allocated to reproductive effort (Pate and Dixon 1981). The season of flowering is a primary consideration for the conservation of such species.

Some species of fauna require special consideration if populations are to be conserved.



landform/soil units 1 : 250, 000





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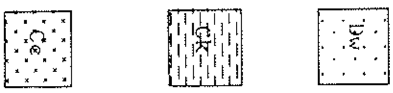


FIGURE 1
Scale in landform soils mapping: an area of the Perup Nature Reserve mapped at 1:250, 000 and 1: 25, 000. Gastrolobium bilobum (heartleaf) has the potential to form thickets on subunits defined at the finer scale enabling the prediction of potential thicket extent.

Plate 1 A stand of *Banksia seminuda* subspecies *remanens* (Hopper, in press) four years after fire in the Walpole-Nornalup National Park. The seedlings that have replaced the stand killed by fire require an estimated minimum of 10 years without fire before producing seed.

Vulnerable animal species are defined with respect to their habitat requirements as those species that are dependent on habitat components that can be eliminated or diminished by disturbance, or are dependent on particular successional stages triggered by disturbance.

Vulnerable species tend to have low population densities (constitutionally rare), be specialists of patchily distributed habitat or successional states, or have low dispersal ability. Species may be vulnerable at the periphery of their range and resilient near their range centre (Hengeveld and Haeck 1981, 1982; Kavanagh and Kellman 1986). Vulnerablity can be exacerbated by fragmentation of habitat, the introduction of, or failure to control, pests and diseases and/or inappropriate management regimes or activities.

Lists of species considered as vulnerable and therefore requiring specific consideration in management should be completed for each reserve. This requires an accurate knowledge of the current distribution of species. The availability of computer-based climatic data retrieval and prediction systems (eg BIOCLIM, Booth *et al* 1988) has enabled the prediction of rare fauna (eg Longmore 1986, Dovey 1987), and potential pest distributions (Van Beurden 1981). The use of such schemes encourages the efficient use of survey and research time and speeds up the mapping of distributions.

The factors governing the distribution of species must also be understood as distributions change with time (Bowers 1986, Rosenweig and Abramsky 1985). Thus an understanding of distributions, and of the factors influencing vulnerablity must be available to ensure that guidelines for the effective management of vulnerable species can be implemented.

Key Taxa

Taxa that fruit, flower or seed outside community peaks in production or that provide other specific habitat requirements may be extraordinarily important in maintaining sedentary vertebrate populations. These have been designated "keystone mutualists" (Leighton and Leighton 1983 after Gilbert 1980) and are referred to as key taxa in this paper. Any species, the removal of which would precipitate significant losses of other species should be considered a key taxa. In a situation of limited resources, those species most critical to the maintenance of a diverse community or crucial to the maintenance of vulnerable species should be targeted first for research and management effort. The identification of these species requires a knowledge of interactions within a system and of species responses following disturbance.

Gastrolobium bilobum (R BR, 1811) is a key taxa in the Perup Nature Reserve where it forms thickets suitable as habitat for the tammar wallaby (Christensen 1980). Specific management operations are necessary to ensure the continued maintenance of suitable habitat for the tammar wallaby in this reserve. In this example, maintaining suitable habitat requires burning prescriptions to produce intense fires under controlled conditions.

Rare species, vulnerable species and key taxa should all be given high priority in the management of fire on nature conservation lands. Species that fit all of these categories are of the greatest priority (eg certain species of Banksia which flower at a time of limiting food resources in a community, are also rare, susceptible to dieback caused by Pythiaceous fungi, and are fire sensitive obligate seed regenerators).

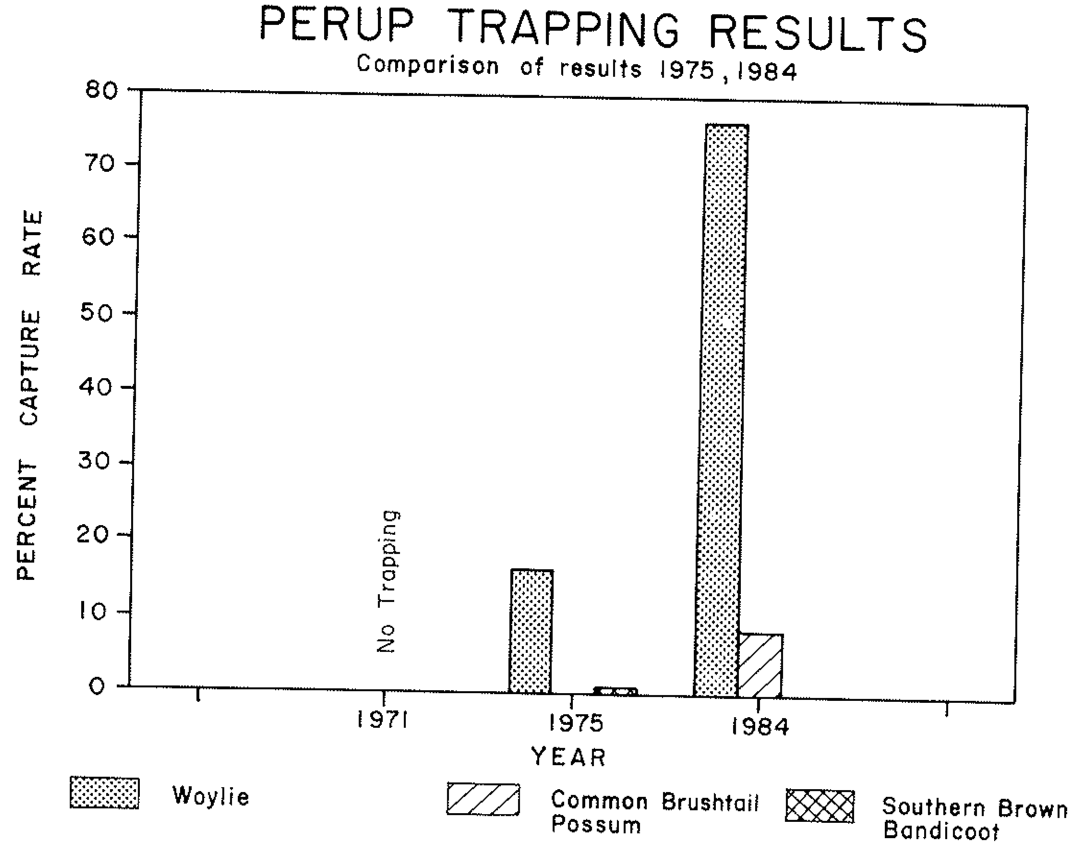
The Role of Monitoring

Monitoring programs are necessary to detect changes that relate to all components of the ecosystems being managed. However, such programs tend to be of little scientific or practical value unless accompanied by corresponding environmental information that allows the process responsible for change to be identified. Similarly, the monitoring must have an explicit hypothesis to be successful in determining whether criteria are being met. It follows that the organism appropriate to the hypothesis should be identified and monitored (see Ridsdill-Smith 1986).

Monitoring of particular species will be of advantage if a relationshp exists between the abundance of several species at any time. Thus low numbers in one species may suggest reason for concern in others. The spatial variation in density and thus comparative suitability of monitoring sites should be known before the establishment of monitoring programs.

Figure 2 shows trapping results in three years in two reserves known to include populations of the Woylie (*Bettongia penicillata* Gray, 1837), common Brushtail Possum (*Trichosurus vulpecula* Kerr, 1792) and Southern Brown Bandicoot (*Isoodon obesulus* Shaw and Nodder, 1797). Different trapping rates for woylies in the two reserves suggest different sized populations. However, population sizes are not static suggesting a need to plan operations designed to manipulate habitat around trends in population levels. Species vary in the ease with which they may be studied and monitored. Efficiency in monitoring time and effort will be achieved if high population densities of easily trapped animals such as the woylie (eg) reflect high populations in other species.

TRAPPING RESULTS FROM TWO RESERVES SHOWING SIMILAR TRENDS IN NUMBER OF ANIMALS TRAPPED



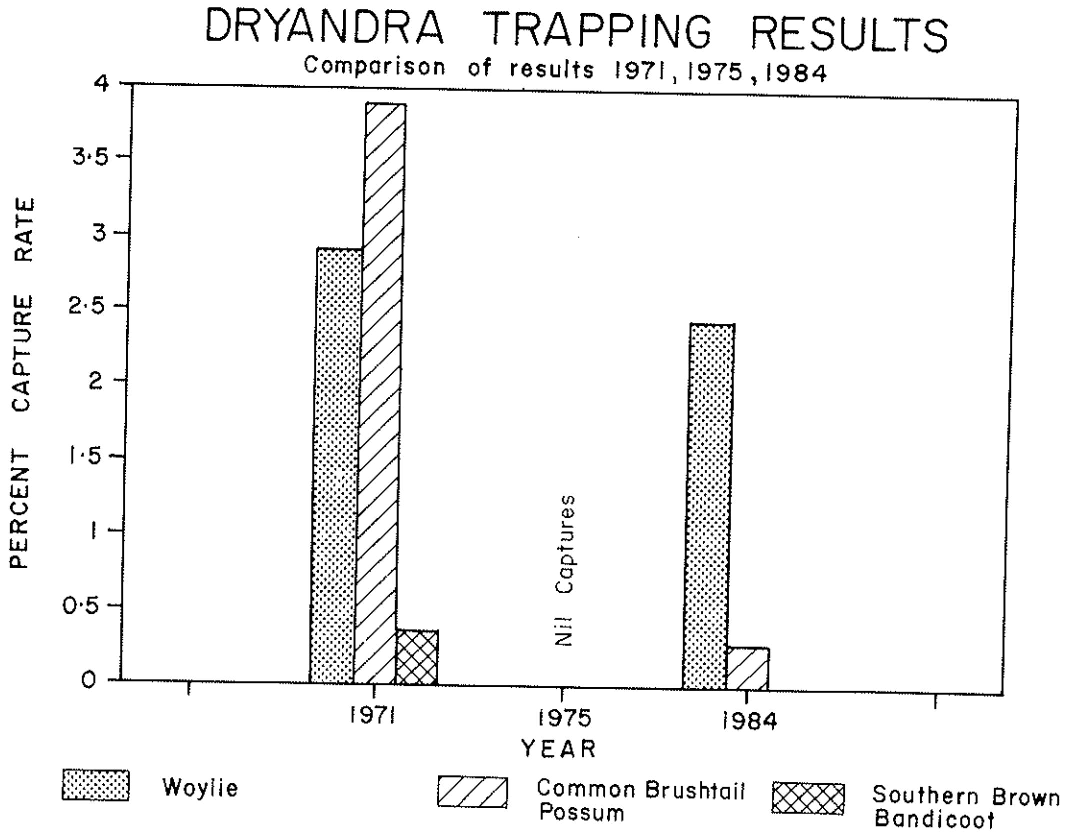


FIGURE 2
Trapping results using box traps in three years in the Perup Nature Reserve and Dryandra State Forest.

Interactions Between Fire, Reserve Users and Neighbours

Management of fire is influenced by political and social factors and objectives for reserve management reflect society's prevailing attitudes and ideas. The cultural environment therefore has considerable influence on the detail of management practices. Major changes in the attitudes of the community towards fire have taken place in the last 150 years in south-western Australia (McCaw and Burrows 1988) and such changes will no doubt continue in the future, probably at an accelerated rate.

Government agencies responsible for management of conservation lands generally must comply with a wide range of legislation. These Acts are therefore an essential part of the critical data requirements. For fire management of conservation lands in Western Australia the Conservation and Land Management Act (1984) and the Bushfires Act (1954) are particularly important. The Wildlife Conservation Act (1950) also contains important provisions relating to the protection of declared rare flora from fire.

Many conservation reserves experience a variety of additional land uses which may range from passive recreation to mining; illegal activities such as wildlife poaching may also occur in some cases. Information about the distribution, extent, nature and timing of these activities is critical, both for determining the risk of ignition posed by these activities, and for determining the degree of hazard to which land users may be exposed during fire. Regular updating may be required if land use patterns are changing rapidly; visitor surveys, regular patrols and periodic remote sensing may all play a role in keeping the data base up to date.

All reserves have neighbours, whether they be private landholders, shires, other government agencies or the Crown. To be effective fire management must be planned on a regional basis, and for this reason the attitudes and policies of neighbours towards fire may have an important bearing on management of fire in a reserve. Effective liaison and participation with volunteer bushfire brigades, local authorities and public interest groups should be fostered as a means for gauging local opinion. In many cases reserve managers may be able to obtain much useful information about a reserve from local people with long experience in the district.

Resources Relative to Management Objectives

Many factors limit the capacity of managers to undertake all fire management operations considered desirable and so priorities must be assigned to ensure that resources are deployed efficiently. Systematic evaluation of the risk of fire ignition and of the hazards posed by fire to different values provides a logical basis for allocating priorities. Hazard rating systems have been developed for national parks in Eastern Australia (Good 1985) and forest areas in Western Australia (Burrows personal communication, Underwood personal communication). Once maps of relative hazard can be generated for individual reserves, priorities can be allocated for modifying or reducing the level of hazard or increasing the opportunities for fire control. Hazard reduction is often considered by some to be synonomous with fuel reduction burning but this need not be the case. Alternatives range from employing other means of fuel modification to relocation of the asset itself away from the perceived hazard, or upgrading fire detection and suppression capabilities.

Management in the Absence of Data

The critical data set suggested here may take some years to compile even for a single reserve. Similarly, data not currently considered critical to fire management may become so as the objectives of fire management of reserves develop. However, management must continue, even in the absence of critical data and interim plans are therefore essential. Necessary management operations can continue even while we know little of the biological pattern and processes of the reserve. However, in such a situation, managers must be conservative in their approach. The following strategies should be employed to minimise disturbance while a more complete understanding of the role of fire in the maintenance of ecosystems is developed:

1 Oppose or defer disruptive activities or interventions where the outcome is uncertain (eg mining, damaging recreational use, activities encouraging weed or pest invasion or major changes to hydrology). Avoid undertaking large scale operations pre-emptive of a management plan (eg major new roadworks).

2 Repair the scars of any previous disruptive activities (eg rehabilitate gravel pits, close poorly sited access tracks, ensure good demarcation between neighbours with different land use policies). Remove undesirable weed or pest species where this does not compromise other conservation objectives.

3 Prevent the entire area of any single community type being burnt at the one time.

4 Liaise with neighbours; encourage an interest in the reserve. Ensure a thorough public involvement in the final management plan process.

5 Encourage the gathering and dissemination of a critical data set for the reserve.

6 Ensure that there is sound justification for every management operation and that the effectiveness of all operations are documented and monitored.

7 Be prepared to move with the times and update management plans as new information comes to light.

8 Adopt a strategy of experimental management (Gill 1986, Hopkins and Saunders 1987) where variations of current operations are tested in areas of greatest resilience. Examine methods of hazard reduction that have the least impact on the biota.

CONCLUSION

Until recently fire management plans have primarily addressed the protection of human values and the management of particular species. With greater public interest, wider knowledge and more sophisticated objectives there is a requirement for more holistic management. This will necessitate a more structured and systematic approach to data collection and analysis. It is therefore essential to define those aspects of the biological, physical and cultural environment that must be researched first to ensure that management concentrates on key issues and is able to become more sophisticated as the needs increase.

Data that aids our understanding of fire regimes and the response of the biota to those regimes are considered critical. Cultural data on the interactions between fire, reserve users and neighbours and the priorities for resource allocation will determine the success of the management of fire on nature conservation lands and must also be considered critical. In the absence of these critical data requirements conservative management strategies should be adopted to ensure minimum disturbance to ecosystems until reliable data on which alternative approaches may be based, are available.

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SETTING STRATEGIES TO ACHIEVE FIRE MANAGEMENT OBJECTIVES

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INTRODUCTION

In Western Australia fire management knowledge of nature reserves can vary from substantial to insignificant depending on the vegetation types. In the jarrah and karri forests of the south west of the state, fire behaviour, fire ecology and habitat management research has been ongoing since the 1960s and 1970s. As a result it is possible to approach fire management planning scientifically by setting specific, quantifiable objectives, and selecting strategies that have a known impact and are likely to be practical and achievable.

Where knowledge of fire behaviour is sparse or totally absent, such as in the spinifex, mallees and heath vegetation types, fire management decisions have had to be somewhat subjective, and are more likely based on historical experiences and intuition than on scientific facts.

The manager entrusted with the responsibility of conserving the nature reserves under his control must plan and implement fire management strategies that permit the protection of human life and property as well as the conservation values in and around the reserve. Where any of these values are high, he cannot adopt a "do-nothing" approach whilst waiting for data and information to be collected. Management strategies must be selected on the basis of existing knowledge, and be flexible enough to allow for integration of additional information gained in the future through the implementation and monitoring of fire regimes and operational trials.

The task of evaluating and selecting suitable fire management strategies is made simpler if the fire management objectives are quantified. For example, if the fire protection objective is that no single wildfire is to burn out more than, say, twenty-five per cent of the reserve and fire is to be contained within the reserve, it becomes clear that a system of strategically located low-fuel buffers in conjunction with an effective suppression system should be considered amongst other strategy alternatives. Similarly, fire ecology objectives can be quantified in this way. An example is in the draft objective for the Two Peoples Bay Nature Reserve which aims, amongst other objectives, to ensure the persistence of viable populations of every species of rare flora and fauna occurring on the reserve. This objective allows for the development of suitable habitat management strategies as well as fire prevention actions. Objectives that are too broad and nebulous cannot be evaluated for their success or failure, and do not lead to the development of specific and adequate strategies.

The Fire Management Planning Process

A model for the processes that are involved in any systematic development, implementation and evaluation of a fire management plan is proposed in Figure 1. This model works through from the initial determination of the reserve management objectives, through to the evaluation and selection of fire management objectives, strategies and works programmes down to the monitoring and review of the effectiveness and impacts of these works on the Reserve.

The starting point is the development of an overall management objective for the reserve. This must accurately reflect the land-use objective for the reserve which has been identified in either the Regional Management Plan or the Department's Statewide land-use management plan.

The second step is to determine the specific fire management objectives for the reserve. Before these specific fire management objectives can be derived however, it is necessary to conduct an analysis to determine the values required to be managed and those at risk to fire damage or inappropriate fire regimes. One systematic approach for a risk analysis is being devised and tested for forest lands within the CALM estate. This procedure termed a "Wildfire Threat Analysis" permits a comparative determination of the probabilities of such questions as: will a fire start?, will it spread?, what values are threatened by fire?, and what can be done to control it?

In most State forest areas of W.A. it has been found possible to place weighted values on those attributes that contribute towards each of these probabilities, and therefore to score and map various combinations of risks and values. The weighting assigned to particular attributes is somewhat subjective and can be open to debate. Nevertheless the structured approach ensures that all important factors of both risks and values are considered. It highlights those areas of greatest importance or with greatest need for care, and provides a framework for decisions on the specific fire management objectives and on the alternatives and priorities for the array of fire management strategies that may be available to achieve the selected objective.

An example of the range of factors considered by CALM in the Wildfire Threat Analysis for forest lands is given in Appendix I.

Selecting the Fire Management Strategies

The next step in the process is to consider all the various alternative strategies that are available for each fire management objective.

It is the task of the planner to determine the most suitable alternative by systematic evaluation of the full range of strategies. Even those alternatives which at first glance appear unacceptable or impractical should be considered. By recording these alternatives it permits those responsible for reviewing the plan to judge the merit of the selected options. The planner or planning group should solicit the information, experiences and opinions that may be available from all relevant groups and individuals interested in the Reserve and the surrounding area.

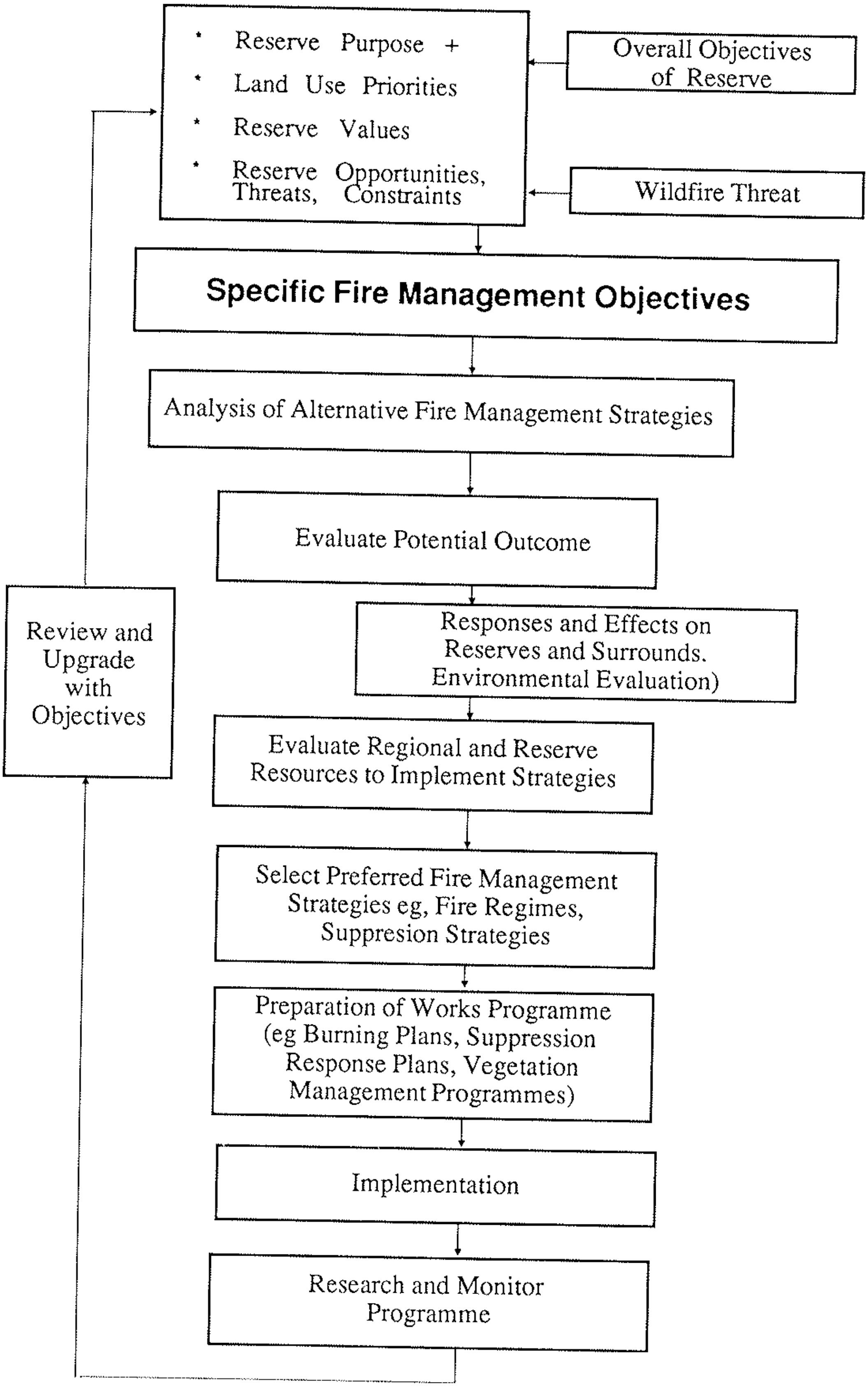

FIGURE 1
Systematic Process for Preparing and Implementing a Fire Management Plan

These may include Departmental experts in the various operational and research sections, fire control agencies, Conservation groups and "Friends of the Reserve", local government, neighbouring land holders, and Reserve user groups. Where a detailed management plan is required, participation by representatives from each of these interest groups in a well-structured workshop can provide a suitable forum for recruiting ideas and opinions on the array of fire management strategies. It is then normal procedure to convene a small representative task force of planners and managers to sieve through the alternatives and evaluate their effectiveness and their likely impacts on the other land management objectives.

In fire management there are a variety of component strategies which can be considered for any reserve. These may include education; law enforcement; local liaison and mutual aid arrangements; firebreak construction and maintenance, fuel reduction methods, vegetation/habitat manipulation operations, recruitment and training, and provision of equipment. The degree to which any of these component strategies are adopted will depend on the values and risks, the likely environmental impact on the Reserve values and the surrounding land, the Reserve location and access, the resources available, and the overall purpose of the reserve and its priority within the Region.

Table 1 lists several examples of the types of fire management strategies that may be applied to achieve some specific fire management objectives and overall management objectives.

The use of prescribed fire as a strategic tool to achieve management objectives is one of the most difficult and controversial issues that need to be addressed by the management organisations. Fire can be used to achieve a number of objectives. Burning for fuel reduction aims to reduce potential fire intensities and rates of spread so the suppression of fires can be facilitated. Fire is also used to regenerate a given ecosystem, or to modify vegetation communities to favour or maintain a vegetation type, seral stage or plant species, or fauna habitats. For a specific unit of land, managers can select and apply the most appropriate fire regime for a particular ecosystem in its social and environmental context. Three different fire regimes are identified by CALM in Western Australia: A "No Fire" Regime; a "Vegetation Management" Regime; and a "Fuel Reduction" Regime. Each of these regimes has a different set of objectives, although frequently their effects overlap. For example, a vegetation management regime can provide adequate fuel reduction and vice versa.

The selection of the appropriate fire regime required for a particular reserve, or part of a reserve can be done systematically through the step-wise approach shown in Figure 2.

Table 1
An example of Fire Management Objectives and Strategies

RESERVE MANAGEMENT OBJECTIVES	SPECIFIC FIRE MANAGEMENT OBJECTIVES	FIRE MANAGEMENT STRATEGY ALTERNATIVES (NOT EXHAUSTIVE)
Conservation of Flora and Fauna	Maintenance of diversity in vegetation association and structures in major vegetation.	° Application of variety of burn regimes in each vegetation type (including fire exclusion).
		° Burn to regenerate/maintain specific habitats.
		° Leave reserve unburnt, except strategic low-fuel buffers to allow wildfires to provide variety.
	Protect to ensure entire reserve not burnt in single wildfire. Variation : ensure only a predetermined (eg, 30% of reserve burnt by wildfire).	° Establish and maintain strategically located low-fuel buffers.
		° Burn parts of reserve in large blocks in mosaic pattern (Patch burn).
		° Fire treatments (both narrow buffers/broad blocks) to include variety of frequencies, intensities, seasons etc.
Protection of Reserve and neighbouring lands	Protect lives (visitors, fire-fighters and staff).	° Provide protective buffers around/within high-use areas, picnic sites, facilities, settlements etc.
		° Maintain road network to allow rapid evacuation and access for fire control.
		° Restrict entry of visitors on extreme days.
	Protect private and public assets in an adjoining Reserve.	° Establish/maintain low-fuel buffers adjacent high value sites.
		° Arrange hazard removal on neighbouring locations/settlements.
		° Maintain fire control access near high risk/high value areas.
	Minimise risks of wildfire starting from human activity.	° Restrict use of fire for camping/cooking etc. Provide gas barbeques.
		° Attempt to modify behaviour of neighbours, Reserve visitors (Pamphlets, Noticeboards etc).
		° Construct/maintain firebreaks.

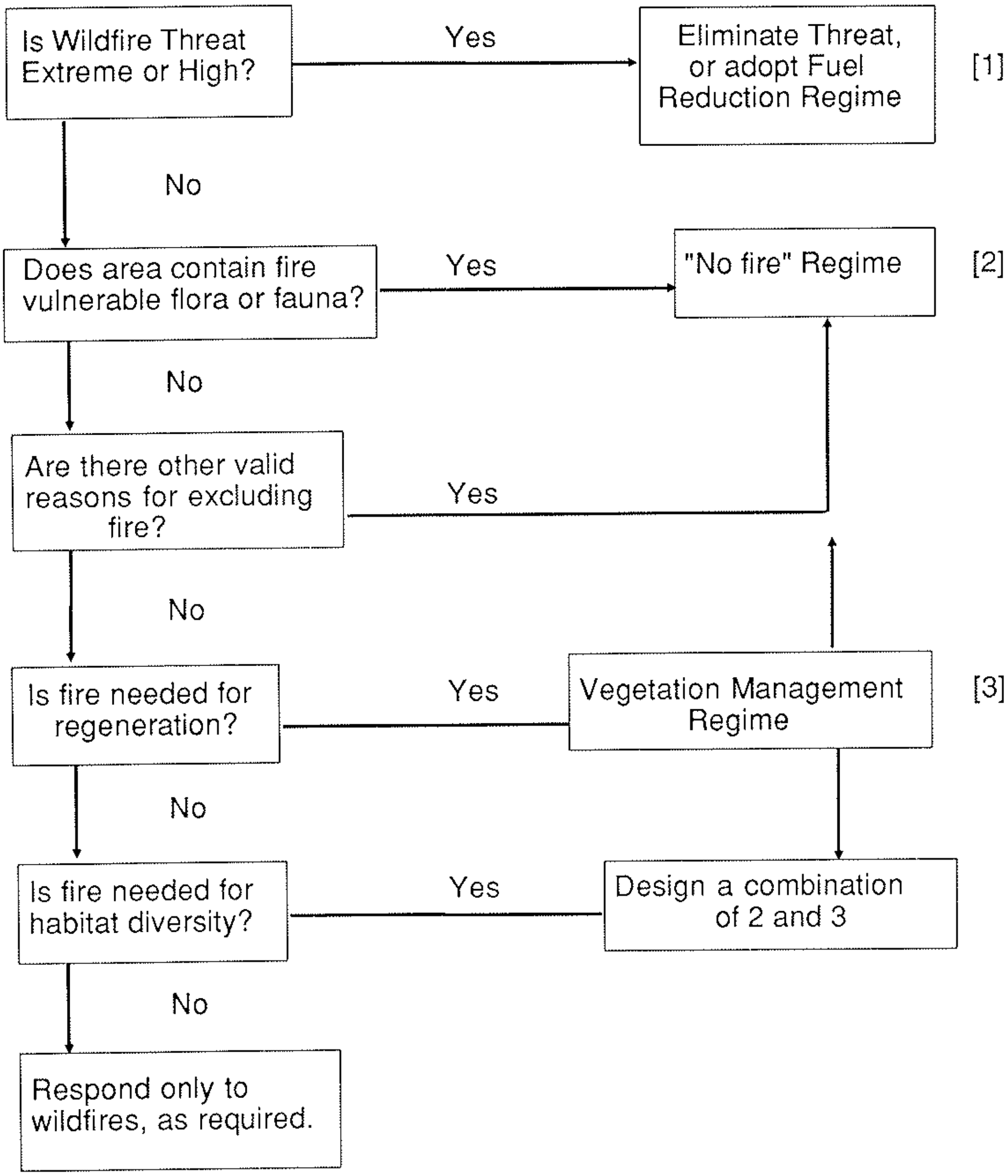

FIGURE 2
Selection of Fire Regimes

Evaluation of Strategy Alternatives

There will inevitably be conflicts between the various fire management strategies, particularly those associated with fire management for conservation, and fire protection of neighbouring lands and community assets. To help identify the conflicts and possible means of resolving such conflicts, it is necessary to work systematically through the planning procedures outlined in Figure 1.

The evaluation process to determine the suitablility of each strategy alternative and its impact on the environment and on other land-use objectives can also be structured to ensure it is systematic and objective. One such systems approach is the Impact Evaluation System for Fire Management Strategies as shown in the Appendix 2. This system enables planners or managers to evaluate potentially adverse or beneficial impacts of a proposed fire management strategy on each of the various components of the reserve ecosystem, as well as on the land-uses in the reserve and on neighbouring lands.

Where the evaluation shows a likely adverse impact, a modified approach should then be considered, and in turn be re-evaluated for its impact. Where there are still likely to be important adverse effects, the proposed strategy (including any modified approaches) may either be rejected, or where it is considered the operation is vital, the decision to proceed will be referred to the appropriate director, or in special cases the Minister responsible. This evaluation system still requires further refinement. Its current emphasis is on the problems and negative factors which prevent or constrain certain strategies and actions, and as a result it may tend to lead to a "do-nothing" decision. A more balanced approach would also include the benefits and opportunities that each strategy may provide to the proper management of the reserve.

Implementation

After the strategies to be applied have been selected, evaluated, perhaps modified, and approved at the appropriate organisational level, the next major process is to spell out the actions, priorities and target dates for each of the strategies. For example where fuel reduction burning is required, the following steps are followed on CALM forest lands:

1 A Master Burning Plan is prepared showing those areas in which fuels will be periodically reduced by prescribed fire. Such plans may also show those areas allocated for other fire regimes. The plan should also designate proposed season of burn, and/or fire intensity. Most forest burn plans may also include a prescribed burn area coverage required to achieve an effective buffer to wildfire.

2 An annual burn program is derived from the Master Plan, in which individual burn jobs are identified and prioritised.

3 Each job is surveyed in detail well in advance of the burn. These assessments include an environmental and safety checklist, fuel type and quantity measurements, and a check of boundaries, problem areas and values requiring special attention.

4 A detailed burn prescription is prepared for each burn in which the ideal lighting pattern and weather and fuel conditions are calculated from the fire behaviour prediction tables. These prescriptions are required to be checked and approved by specialist staff. The preparations and burning of job boundaries (or "edges"), and the core ignition either by ground crews or aircraft must follow very strict and well-rehearsed departmental operational instructions and guidelines.

5 All completed burns are assessed to check compliance with the burn prescription. Records of the post-burn assessments are stored for future reference by the operations staff and fire research specialists.

DISCUSSION

The planning and implementation of fire management policies requires a comprehensive and systematic approach by managers, planners and operators. In many areas, decisions on fire management strategies are still necessarily intuitive. In recent years, however, the process has become more formal and structured. Bitter and sweet experiences, and the products of research and monitoring programs are constantly providing new information and ideas on the most appropriate means to tackle what are often regarded as very complex fire management problems. This paper provides a number of systematic procedures which can be used today by those responsible for fire management planning and implementation.

Appendix 1
Wildfire Threat Analysis

The Threat Analysis has two components: (i) What are the risks? and (ii) What are the values at stake? Under each heading, a range of factors can be considered. The factors are:

RISKS

Risk of Ignition

High

- Regular path of summer storms and lighning strikes recorded.
- Active land clearing within 3 km of site.
- Fire used/planned on adjoining lands (eg regeneration burns, stubble burns).
- High visitor use on site involving use of fire (eg barbeques, marron fires).
- History of past ignitions from other sources (eg deliberate lightings).

Moderate

- History indicates little/no past ignition.
- Moderate visitor use, reasonable access for visitors.

Low

- No history of fires.
- Little/no human activity at or near site, poor access for visitors.
- Summer storms rare. No recorded lightning strikes during the period when fires could start.

Detection Capability

- Poor - no spotter or tower coverage, sparsely populated.
- Fair - infrequent spotter coverage, few towers, moderately populated.
- Good - regular spotter coverage, good tower coverage.

Suppression (attack) Capacity (Crew time to site)

- No fire crews available.
- Crews available within 2-3 hours travel time.
- 1-2 hours } adjust according
- 0.5 to 1 hour } to size of
- 0.5 hours } available crews.

Access around Fire

- Area poorly roaded. Off-road access difficult (heavily timbered, dense scrub, creeks and gullies, dunes or swamps).
- Access moderate - open forest, moderate scrub density, even slopes.
- Area well roaded. Off-road access easy, open country, flat, heath or grasslands.
- Adjust according to effects of topography on fire behaviour.

Fuels

- Very heavy fuels 2 x standard fuels.
- Heavy fuels 1.5-2.0 x standard fuels.
- Moderate fuels 1.0-1.5 x standard fuels.
- Light fuels 0.5-1.0 x standard fuels.
- Very light fuels 0.5 x standard fuels.

The word "standard" in this context applies to the area or botanical association being considered. Different standards apply in different areas.

Dieback Risk from Mechanical Fire Fighting

- High
- Moderate
- None

Wind

- Grass or heathlands (wind ratio 1:1)
- Open woodland (wind ratio 3:1)
- Moderate forest (wind ratio 4:1)
- Medium dense (wind ratio 5:1)
- Dense forest (K1 & 2, regrowth, wind ratio 7:1)

VALUES

Conservation Values

Flora and fauna

- High - If gazetted rare species are present.
- Medium - If geographically restricted species are present.
- Low - If neither are present.

Maturity of vegetation assemblage

- High - If the block is the longest unburnt in its vegetation type in the reserve.
- Medium - If it is the second longest unburnt in its vegetation type in the reserve.
- Low - Otherwise.

Presence of fire vulnerable flora

- High - If there are species vulnerable to fires over 10 years apart.
- Medium - If there are species vulnerable to fires from 5-10 years apart.
- Low - Otherwise.

Extra value as habitat if left unburnt

- High - If there are known to be species of fauna requiring mature vegetation for habitat.
- Medium - If it is likely that there are species of fauna requiring mature vegetation for habitat.
- Low - Otherwise.

Social/Economic Values

Life and Property

- Within 3 km NW to NE of areas where assets/lives concentrated and at potential risk in the event of fire. Eg Townships and settlements. Fixed camps used in summer. Areas where very large numbers of people congregate in summer and cannot be readily evacuated/find refuge in the event of fire.

- Within 3 km (other directions) of above.

- Within 3-6 km of first point above.

- Within 3 km of areas where lesser numbers of people congregate (eg major recreation sites).

- Within 1 km of developed private property.

- Honey, wildflowers, timber, water resources

- Within 3 km generally north-west to north-east of high value production forest susceptible to damage by wildfire. This may include private plantations, regeneration areas and other nominated Red Action areas.

- Within 3 km of lesser value fire sensitive forest (eg smaller patches of regeneration, minor pine areas, important wildflower or honey areas) or is a catchment protection or water production area that would be damaged by wildfire.

- Within 3 km of high value or high quality mature hardwood forest.

- Within 3 km of multiple use forest other than first two points above.

Cultural Values

- The area contains or adjoins areas with important anthropological or historical values which could be degraded by fire.

APPENDIX 11

NECESSARY OPERATIONS IMPACT EVALUATION CHECKLIST

1. PARK, RESERVE, DISTRICT INVOLVED.

   LOCATION WITHIN RESERVE (block, etc)

   PRIMARY MANAGEMENT OBJECTIVE OF THE RESERVE

2. THE WORK PROPOSED - PURPOSE

   TYPE & EXTENT OF THE WORK

3. ANY OTHER OPTIONS AVAILABLE? Specify,

4. IMPLICATIONS OF "DO NOTHING" OPTION OR POSTPONEMENT

INSTRUCTION: Indicate with (✓) or (✗) in Column (1) if proposed work is acceptable or not with respect to the environmental and management issues listed. If not acceptable, consider acceptability of modified proposal in column (2), or 'do nothing' option column (3). Use column (4) for additional comments.	[1] Proposal Acceptable	[2] Modification Acceptable	[3] Do Nothing Acceptable	[4] COMMENT Indicate action required to overcome/minimize adverse impact.
ISSUE	✓ / ✗	✓ / ✗	✓ / ✗	
1. GEOLOGY, SOILS, WATER, AIR				
1.1 Caves, fossils, dunes				
1.2 Soil erosion/damage				
1.3 Streams salinity, sediment, run-off, drainage				
1.4 Air quality, visability				
2. FLORA, FAUNA AND ECOSYSTEMS				
2.1 Gazetted rare, restricted distributed plants				
2.2 Fire sensitive plants, wildlfower display				
2.3 Rare fauna, special habitats				
2.4 Stream, swamps, lakes, gorges, rock outcrops etc.				

ISSUE	[1]	[2]	[3]	[4]
3. ENVIRONMENTAL PROTECTION				
3.1 Disease (eg. dieback, insects)				
3.2 Weeds, feral animals				
3.3 Requirement for gravel, rock, borrow pits				
3.4 Modify fire regime/patterns				
4. CULTURAL HERITAGE, SPECIAL VALUES				
4.1 Aboriginal sites				
4.2 Historic sites, facilities				
4.3 Special reference sites, research plots				
4.4 High value sites, (farms, settlements, plantations etc)				
5. RECREATION, ACCESS, OTHER USES				
5.1 Public access, re-direct public use				
5.2 Increase public mis-use (eg. tracks degrade)				
5.3 Landscape, features, wilderness appreciation				
5.4 Visitor safety				
5.5 Increase demand for facilities and services (eg. rubbish disposal, toilets etc.)				
6. MANAGEMENT CONSIDERATIONS				
6.1 Can proposal pre-empt future Management Plan.				
6.2 Conflict with existing policy				
6.3 Neighbours, local shires, community interests, Apiarists				
6.4 Fulfill legal requirements (eg. Bushfirest Act, etc)				

7. ENDORSEMENT/APPROVAL

PROPOSER ______________________________ Date ____________

DISTRICT/REGIONAL MANAGER ENDORSEMENT/COMMENT

______________________________ Date ____________

APPROVED/NOT APPROVED

______________________________ Date ____________

FIRE MANAGEMENT FROM THE GENERAL TO THE PARTICULAR

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SUMMARY

Strategy is the setting of objectives and outlining how they are to be achieved. It is based on legislative requirements; policy, both stated and unstated; data, including resource data, scientific data and experience; and the social/political environment. This is transformed into fire management strategies for both wildfires and planned fires.

Fire control strategies for wildfires are basically aimed at the protection of life and property with "let burn" options being contentious.

Fuel management regimes using planned fire are used to reduce fuels and/or modify habitats. Options to be considered are strategic or broad area burns, single or multi-stage burns, as well as variations in timing, frequency and intensity. Treatments vary from specific to general, to either favour a particular plant or animal, or maintain diversity on a broader scale. A "no burn" option must receive the same detailed consideration as other possibilities.

Land managers must develop strategies founded on the best information available, detail the compromises necessary, seek public and institutional input, initiate action, and review the situation constantly in the light of changing circumstances and availability of new data.

All strategies are necessarily compromises as it is impossible to meet all requirements and pressures. Contentious issues are likely to be decided at an emotional/political level rather than being based on scientific evidence.

INTRODUCTION

This paper explores some of the factors influencing the manager of Conservation Lands and how these are translated into fire strategies. On one hand a land manager is faced with vast amounts of conflicting, incomplete information, policies and opinions. On the other side there are constraints of limited resources, time, and money, with often limited data and experience to guide the manager. In addition it is necessary to take positive action, rather than sit on the sideline and see what develops. All this must be turned into strategies for both wildfires and planned fires.

There are many items which provide the basis for determining strategies. These include:

(a) legislative, which are often generalisations and can be interpreted in many ways;

(b) policies of the organisation, which may be stated in policy documents, inherent in the organisation and recognised by all, or may be deliberately unstated but understood;

(c) data, including inventories or assessments of the resource, scientific theories and experience covering cause and effect relationships; and

(d) social/political, which are the perceived demands of the community, both local and at large. These demands are often misguided, insular, and very often polarised.

Wildfires

It is essential that the land manager develop strategies to handle the serious, intense, disastrous fire - the holocaust. If this is done the minor fires, representing ninety-five to ninety-eight per cent of all fires, will cause no great problems. However, if the strategies are based on the majority of fires they will be inadequate for the important fires. There will be no technology available now or in the future to combat an intense wildfire. The only feasible strategy is fuel modification and reduction. If the land manager does not implement this then there is a good chance he will have to answer to a Coroner and his conscience. It is an abrogation of responsibility to accept major intense fires as "natural" or "an integral part of the management of natural areas". The manager must manage his reserve to achieve the desired goals for the area.

Through adequate and proper training and planning the land manager can prevent injuries to firefighters, protect lives and property and minimise damage to conservation values. It is necessary to know the location and importance of various environmental constitutents so that protection strategies can include appropriate priorities.

There is a continuum of strategies for managing wildfires which are illustrated in Table 1. Generally the intention is to establish and consolidate control lines, burning out if necessary as quickly as possible to minimise costs, damage and the chance of breakouts if conditions deteriorate. Following from this is the acceptance, except in some remote areas of low population density, that any strategy that embraces a "let burn" possibility is completely unacceptable. Given the current state of the art of weather forecasting all fires must be considered to have a high potential for causing damage. An unacceptably high proportion of the classic devastating fires in Australia were from "let burn" situations (eg Victoria 1939, Hobart 1964, New South Wales 1968).

Planned Fire

All planned fires reduce fuels and modify habitats regardless of the original reason they were planned. There are a number of factors which influence planned fires and affect the results achieved. Most of these cannot be modified or controlled so all planning and strategies must be based on recognising suitable conditions when they occur and taking advantage of them.

These are:

(a) fire behaviour which is controlled by climatic factors, current weather, fuel characteristics and topography;

(b) timing of the burn in terms of both time of day and season;

(c) frequency, which has several aspects; (The period between burns can be varied but it is impossible to maintain a fixed frequency due to the vagaries of climate and weather. The areas also can be burnt in stages with the more flammable sections being treated under milder conditions.)

(d) area which can vary from restricted small strategic areas to large broad area burns.

To achieve the desired results strategies are developed by integrating all the factors. The basic steps in developing strategies follow:

Aims

The conditions to be achieved by fire management are defined. These are based on the best information available and are specified in terms of fuel remaining (quantity and arrangement), time of year of burn, frequency, acceptable limits for scorch, and proportion of area covered.

Inventory

Detailed, accurate measurements of current conditions are needed as a basis for burning prescriptions and for comparison with the position after burning. Permanent sampling points/plots should be established. Items to be recorded include fuel details (eg quantity, arrangements), flora and fauna, past perturbations (eg fire, clearing, erosion).

Prescription

Based on consideration of all or any guides available (eg McArthur, Rothermel, Peet) and experience, a prescription for the trial treatment is formulated. This will be some form of an index which integrates the various weather and fuel factors which influence fire behaviour. Limits also have to be set on weather factors (eg no burn above 20 per cent or below 30 per cent RH). The method and pattern of ignition is also specified.

Test

When an acceptable balance of conditions occurs light up the test fire. The area treated must be big enough to ensure full development of the burn. Weather conditions during the burn are to be recorded as well as behaviour of the fire. Ensure that the method and pattern of ignition specified is followed closely as many anomalous results (disasters) have been caused by enthusiastic workmen lighting up a bit extra to ensure a "good" burn.

Monitor

The effects of the fire should be carefully monitored for some time after the fire.

Evaluate

The results of the fire and all other fires are considered and used as a basis for setting new prescriptions to be tried.

Repeat

By this process experience and burning guides are developed.

Usually there are numerous combinations of factors which will achieve the desired burn and this needs to be reflected in the guides so that no opportunities are missed. To allow for the vagaries of climate and weather the manager must have sufficient plans prepared to cover three years average treated area to ensure the optimum use of suitable conditions when they occur.

All strategies are essentially compromises and it is the responsibility of the manager to determine the one most suitable for the situation. Although there are a great number of possible strategies they generally fall into a few main groups:

Strategic

Low fuel levels are maintained in an attempt to provide barriers which are difficult for wildfires to cross. They are usually for a specific reason such as the protection of a particular resource. They may also be used to prevent a fire from escaping from an area if, for instance, a high intensity fire was to be applied for some reason.

Specific

These are burns designed to achieve a narrowly defined objective such as favouring a specific animal or plant. They can vary in intensity from no burning to a holocaust. Problems are caused because of unexpected interactions, with possible detrimental effects on other elements of the environment.

Broad area

These are intended to reduce the chance of a holocaust over a relatively large area. Because of variations in vegetation types, fuels and topography, the intensity of the burn also varies so that diversity is maintained or enhanced. Usually fire intensity is kept low to minimise damage and a second burn under more severe weather conditions may be used to achieve a more complete treatment.

No Burn

For a variety of reasons it will be decided to attempt to exclude fire from an area. This is a conscious planned decision, but managers must accept the possibility that it may be burnt in unforseen circumstances.

GENERAL

Several aspects not covered above include:

Initial Treatment

In many cases the first planned fire in an area presents problems. Fuel levels may be much higher than required or their distribution may be undesirable. Care must be exercised to ensure a safe acceptable result from the initial fire. The managers job is much easier for subsequent burns.

Transition

In most cases where a reserve is created the future land management intended is quite different from that previously practised. The change in emphasis in fire management can be achieved quite smoothly provided it is planned and executed in conjunction with the local community, taking into account their concerns, both real and imagined. However, if the change is imposed abruptly without consultation problems can surface. If the local community perceives, rightly or wrongly, that the changed management may expose it to a dangerous situation, residents may reduce the fuel with illegal fires. If an uncompromising attitude is allowed to continue an isolationist, seige mentality develops. The problem becomes deeply entrenched and increasingly difficult to overcome.

Insufficient Information

Land managers cannot excuse inaction on the ground that there is not enough data/information/evidence on which to base their actions. A manager must act on the information available and build up expertise by experience. The number and complexity of variables involved in fire and land management means that actions will more often be based on developed experience rather than on controlled research. Managers must be encouraged to build up their expertise and not be castigated if results are unexpected or unacceptable. It is most unlikely that "unacceptable" results are irreversable.

The course that a land manager should follow to develop strategies and implement them has been set out in general terms. This course should be pursued vigorously as this is the manager's role.

Table 1
Phases of Forest Fires

	Fire			Strategy			Organisation			
PHASE	BEHAVIOUR	WEATHER FUEL	COSTS DAMAGE	POSITION APPROACH	ATTACK	PRIORITIES	AUTHORITY CREWS	ORGANISATION	CONTROLLER	CO-ORDINATOR
I SMALL	small, slow moving	calm	negligible	offensive	aggressive, direct head-on	immediate suppression	1 + 1	simple	Foreman	Foreman
II MODERATE	developing some high flames	either worse weather or heavier fuel	low cost neg. damage	offensive	aggressive direct/indirect	hold all lines	1 autho. 2-3 crews	simple	Foreman	Forester
III LARGE	free-burning, uncontained	deteriorating, heavy fuel	moderate cost, some damage	offensive defensive	indirect close up flanks	hold main lines	1-2 auth. 5-10 crews	simple	Forester	District Forester
IV VERYLARGE	uncontrolled, complex, some spotting	severe weather, heavy fuel	expensive, major damage	defensive offensive	indirect, remote, complex	hold some lines, protect life and property	2 + auth. 10 + crews	complex	District Forester	Regional Forester
V CATASTROPHIC	very complex, out of control, intense spotting	extreme weather, heavy fuel	extremely costly massive damage	defensive	v. complex, retreat, wait for weather c change	only life or life and property	many/all available	very complex (chaotic)	D/F. + helpers	R/F. + helpers

APPROPRIATE FIRE MANAGEMENT STRATEGIES FOR THE NORTHERN TERRITORY

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SUMMARY

A broad framework for the development of guidelines for fire management in the Northern Territory is presented.

Strategies in place in the Northern Territory are briefly described. These include a collaborative study by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Conservation Commission of the Northern Territory (CCNT) in the southern half of the Northern Territory; "Anticipating the Inevitable", the patch burning strategy for Uluru National Park; a Fire Management Manual for parks and reserves in Central Australia; aerial burning in the "Top End"; and fire management of "Top End" parks and reserves.

INTRODUCTION

Appropriate fire management strategies, whether at the Northern Territory, regional, or park level are those which reflect the best compromise between what is perceived as the ideal situation and constraints including:

- lack of quantified objectives;
- lack of resources;
- lack of fire behaviour and effects information, and other relevant resource data;
- complexity of vegetation distribution and lack of mapping;
- social perceptions of the role of fire;
- conflicting ideologies between those responsible for land management;
- the complexity or boundary situations and land tenure;
- the requirement to protect life and assets;
- changing structural organisation of institutions responsible for fire management.

The institutionalised development of fire management strategies in the Northern Territory (NT) is a relatively recent activity and was originally largely based on an element of intuition. Strategies have since evolved through the combined process of direct management experience, input from research and adoption of new technology.

Fire management strategies at work in the NT vary widely in the quality and quantity of their information bases, the level of planning detail and the complexity of management practices. Preparation of fire management plans does not take place under a single planning model. However, all strategies in the fire-prone Territory landscape are guided by, or have as their starting point, a few basic principles. The comment must be made that lack of sophistication does not equate with lack of effectiveness. Aboriginal strategies, as described by numerous authors, lacked all the material trappings of current strategies in terms of data bases and predictive models but were most effective in maintaining a stable landscape over a period of 30 000 years.

This paper provides an overview of the background against which the broad recommendations for fire management have been developed in the Northern Territory. The second section of the paper briefly outlines the more salient strategic fire management activities of the Conservation Commission of the Northern Territory.

Extent of "Conservation Lands" in the Northern Territory and the Responsibility for Fire Management

The Northern Territory landscape has not had a complex land-use pattern. The major land-use categories are those related to Aboriginal activities, grazing and conservation, with tourism superimposed over all three. All these land-uses are either wholly dependent or closely linked in material and intangible ways to the native vegetation cover. The dependence of major land-uses on native vegetation adapted to fire creates a requirement for the managed application of fire over much of the Northern Territory.

The legislative framework for strategic planning of fire management activities in the NT is provided by the NT Bushfires Act 1980, the NT Conservation Commission Act, and the Territory Parks and Wildlife Conservation Act 1980. The Bushfires Act (1980) provides the authority to prevent and control bushfires in the NT to the NT Bushfires Council (BFC), a statutory organisation but administratively attached to the Conservation Commission. The BFC provides extension services to the major landholders in the NT (ie pastoralists and Aboriginal). The Northern Territory Conservation Commission Act has the promotion of conservation and protection of the natural environment throughout the Northern Territory as the initial item in its statement of functions.

The Territory Parks and Wildlife Conservation Act, 1980 provides for the preparation of plans of management to ensure proper management of parks and reserves. While there are no specific provisions under the Act relating to prescribed burning, any fire management activities must be carried out in accordance with the management plan.

Where no plans of management exist the Commission is authorised to perform its function to preserve and protect the park or reserve. This also provides a basis for fire management. The Commission is currently responsible for the management of approximately eighty-four areas comprising 1.8 per cent of the Northern Territory (Mobbs 1986). The Commission is also actively involved in research into fire behaviour and effects.

Fire Management in the Northern Territory - A Historical Perspective

The application of fire by Aboriginals in the NT over a period of 30 000 years has been described by Jones (1969), Haynes (1985), and Latz and Griffin (1978).

Pastoralists in the higher rainfall areas of the NT have used fire in an intuitive manner for over one hundred years to promote native pasture production and assist with mustering (Norman 1963; Perry 1960). Anecedotal information exists on the fire practices of pastoralists early this century in central Australia (Portlock, personal communication).

Significant direct government involvement in fire management commenced about 1966 with the creation of the NT Bushfire Council and the work of professional ecologists in the precursors of the Conservation Commission. Aerial burning was trialled in the Top End in 1967-68 with the notion of maintaining past practices and ameliorating the effects of late dry season fires. Aerial burning was also conducted on a limited scale on the southern side of the Tanami Desert during this time for two reasons:

(a) the perception that there was a large area of spinifex carrying a heavy fuel load posing a threat to centralian pastoral areas and stations hundreds of kilometres to the north; and

(b) the notion that this build-up of older even-aged spinifex was an unsuitable habitat for colonies of rare wallabies thought to exist in the area.

The impetus for active fire management and research was maintained in the Top End from the early 1970s onwards. However, in central Australian rangelands, with the onset of record rains and extensive fires, management was aimed solely at protection, through the construction of fire breaks as a preventative measure, or by direct suppression efforts.

In the late 1970s, a substantial program of fire research was established in central Australia and attitudes to fire changed. A consensus of opinion for active use of fire by land managers in central Australia now exists.

Climate, Vegetation and Fire in the Northern Territory

The Top End

The monsoon climate of the Top End is characterised by a marked wet and dry season. Almost all rain falls over the summer period, October to April. The average rainfall in Darwin is 1 600 mm and by rough rule of thumb, drops by one milimetre for every kilometre travelled inland.

When viewed from a smaller scale, the Top End is dominated by eucalypt open forest and woodland with extensive floodplains in coastal areas. At a larger scale, the predominant open forest and woodland comprise monsoon forest, paperbark and seasonal swamp forests. Descriptions of the floristics, structure and distribution of Top End vegetation can be found in Christian and Stewart (1953) and Storey (1969, 1976). A simple description of fuel dynamics is outlined by Cheney (1979) and Hoare (1985).

Within the area of monsoonal influence "fire is an integral part of the environment for its appearance in many plant communities is annual and it comes as surely as the rain of the wet season monsoon" (Stocker and Mott 1981). However, information on fire patterns for the "Top End" is available only for a few areas (Day 1985) and consequently no comprehensive annual statistics on total area burnt or individual fire size exist. Hoare (1985) describes broad fire patterns as dictated by climate and fuel state for Top End forests and woodlands.

Stocker (1966) recorded observations on Aboriginal and European use of fire and the effect on selected plant communities in the NT. He also made broad recommendations for fire management in the Top End and the lower rainfall areas of the NT. Stocker's basic observations and recommendations are found in all subsequent literature dealing with fire effects and recommendations for management in the Top End.

The major determinants of vegetation distribution in coastal regions are moisture availability in the dry season and the degree of flooding (soil oxygen supply) in the wet season. These two factors are strongly influenced by topographic position and soil type ie vegetation is closely aligned to landform and soil type (Bowman 1987).

However, within the open forest/woodlands of the Top End, Hoare *et al* (1980), had as one of its main aims, the provision of quantitative information on the fire/vegetation interaction to those responsible for land management in the Top End. The key recommendations based on their findings were:

(a) a system of planned fire management be adopted;

(b) early dry season biennial fires be adopted for large area hazard reduction; and

(c) fires of low intensity with flame height of less than 1.5 m be applied in the early part of the dry season and at intervals between three and five years to obtain optimal vegetation and habitat development.

The Centre

The climate of central Australia is characterised by extreme variability of rainfall, both seasonally and annually. Droughts occur seasonally and annually with durations from less than one year to fifteen years. Pluvial periods occur between droughts but are usually of short duration.

The vegetation of the NT's arid zone has been described by Perry (1960). A simple description of fuel type, dynamics and fire pattern in four broad fuel/vegetation areas is contained in Griffin *et al* (1983). Area burnt and number of fires was correlated with three years of cumulative antecedent rainfall. In the absence of management intervention, the wildfire regime in central Australia is one of extensive wildfires following periods of above average rains.

Fire effects at the community level in central Australia are complex and vary depending on, among other things, the timing of fire in relation to maturity/seral development of the community.

Griffin (1984) suggests that for conservation lands, fires should only be lit in mature habitats, ie where all species in the community have had time to reproduce and develop sufficient fuel to carry another fire. Significant, in some cases apparently irreversible, changes in structure and floristics can take place in some central Australian plant communities (eg Mulga) if multiple fires occur in earlier stages of seral development.

From the park manager's point of view, the main effect of extensive wildfire is the possibility of burning the entire park in a single fire and reducing the area to a uniform successional stage. Depending on past fire events, the potential exists for significant change in park vegetation under such a regime.

The patch burning strategy put forward by Saxon (1984) and Preece (1987), has two main effects; it ensures a diversity of vegetation stages, and it prevents wildfire covering all the park in one event. Prescribed burning of patches also allows protection of rare and/or fire sensitive species and provides long burnt/unburnt edges which are ideal habitat for some animals (eg Mala *Largorchestes hirsutus* colonies of the southern Tanami).

Fire Management Strategies in the Centre

The following three examples indicate separate bases for fire management strategies operating in central Australia:

(a) Collaborative Commonwealth Scientific Industrial Research Organisation/Conservation Commission of the Northern Territory studies;

(b) "Anticipating the Inevitable", a patch burning strategy for Uluru; and

(c) Fire Management Manual for Central Australian Parks and Reserves.

The impetus for development of these strategies came directly from the initiation of research work in the late 1970s.

The aim of the collaborative CSIRO/CCNT study was to provide fire managers with information on fire history, fuel load, ecological maturity and fire behaviour for the southern half of the NT. Emphasis in the study was given to spinifex dominated communities.

Mapping the fire history of the southern half of the Territory has been completed using a combination of satellite imagery, aerial photos and Bush Fire Council records. The maps have been digitised and updating will be carried out via analysis of US National Ocean and Atmospheric (NOAA) satellite imagery. The data relating to each mapped fire are stored on computer.

The product of this research effort is a system that rapidly accesses and collates information for decisions on wildfire or prescription burning in spinifex areas and to varying degrees in other fuel types in the southern part of the NT below latitude 20°S.

As an extension of the above collaborative study a fire management strategy was developed for Uluru and was published in a booklet titled "Anticipating the inevitable: a patch-burn strategy for Uluru (Ayers Rock - Mt Olga) National Park" (Saxon 1984). Proposed patch burns were located in concentric zones around selected fire sensitive segments of the park. Locations and prescriptions for patch burning were based on examination of fuel loading, maturity of vegetation and fire behaviour in twenty-one land units, and an additional number of facets within land units.

The actual implementation is left to park managers. While the strategy has been applied on the ground at Uluru the development of this strategy can be regarded as a research project.

The approach certainly provides a guide for the development of strategies in other areas. However, the resources and expertise used to assemble the data bases on which the strategy was developed are not available to those responsible for fire management on other lands in the centre.

The "Fire Management Manual for Parks and Reserves in Central Australia" (Preece 1987) presents a formal framework for planning and controlling fire management on a large number of diverse parks. The manual details planning activities in three phases: pre-burning preparation, implementation, and post-burning action. Planning in the pre-burning phase involves the identification of rare and endangered species, fire sensitive communities, communities at a desired stage of seral development and location of patch burns to protect the above communities and prevent the loss of the entire park area in one fire event, (usually done on the basis of fuel loads). The actual burning is carried out under the supervision of staff with long term local fire knowledge.

Planning of patch burning activities on parks is done on an annual basis. However, the desirability of adopting a longer planning horizon is recognised.

Fire Management Strategies in the Top End

Aerial Burning in the Top End

An annual program of aerial burning is conducted by the Bushfire Council on pastoral properties, Aboriginal lands, and CCNT parks and reserves in accordance with park fire management plans.

The annual program cannot be tightly prescribed because of logistical considerations and annual variation in fuel curing rates from region to region. The flexibility of the program is one of its main strengths. The program has been established over a period of twenty years and staff associated with it have developed a high level of expertise in its execution. In particular, this expertise coupled with the local landholders knowledge of fuel curing rates, identifies the upper limits for burning and the majority of burns are of low intensity. The program is accepted by the Top End rural community and is highly effective.

The 1987 program, for example, involved 129 hours of flying (mostly with a fixed-wing aircraft) and the establishment of an extensive system of strategically located burnt breaks by dropping of incendiaries. Assessment of the results of the program are qualitative and are again made on the basis of local landholder knowledge and accumulated experience by the Regional Fire Control Officer. There are two areas where improvement could be made.

1 quantitative assessment of fuel curing rates throughout the area covered by the operation; and

2 mapping of annual fire patterns in the "Top End" including the burning carried out by the Bushfire Council.

Fire Management of Top End Parks and Reserves

With the recent restructuring of the Northern Territory Conservation Commission, overall responsibility for planning and conducting burns in Top End reserves has been regionalised with planning mostly carried out by senior district rangers. This decentralisation has led to non-uniformity of the documentation of individual fire management plans. However, this situation is currently not an impediment to adequate fire management at the individual park level.

On Top End reserves, fire management is gradually moving away from more extensive practices (eg aerial burning), to more intensive forms of management, especially around sensitive areas (eg monsoon forest pockets, crocodile breeding areas, wetland areas used by nesting waterfowl, and paperbark communities). These areas are well-known at the local level and field staff generally have sufficient experience to conduct onground multi-stage burns around the perimeters of these areas to protect them. Where local park staff do not have adequate fire experience to carry out such burning, the district ranger can call on an extensive pool of expertise residing in other sections of the Commission.

CONCLUSION

Widespread NT community acceptance of active fire management has resulted from clarification of the principles underlying management practices and the consolidation of the biological rationale for burning by relatively recent research.

Strategic planners in the NT must continue to focus on the requirements of local operational field staff. The incorporation of research findings into locally available information bases and their translation into improved practices are the key elements in the development of appropriate strategies.

The adoption of a systematic process for the development of appropriate strategies at all levels of management will lead to increase in on-ground effectiveness and efficiency in fire management.

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REALITIES AND CONSTRAINTS, OPPORTUNITIES AND CHALLENGES: FIRE MANAGEMENT IN CONSERVATION LANDS IN WESTERN AUSTRALIA

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SUMMARY

This paper examines some of the many factors which influence fire management programs; for example technical, legal, ecological, economic and social.

INTRODUCTION

In the reality of field operations, there are many factors which may affect the outcome of proposed fire management programs. These may include technical, economic, social, legal and ecological considerations. A number of relevant factors are listed in Table 1. This list is meant to be indicative rather than exhaustive. In addition, the economic, social, legal categories are quite arbitrary and many of these factors may be listed under more than one heading. Because there are many factors to consider, only a few will be discussed in more detail in this paper.

The title of this theme "constraints and considerations" may cause us to concentrate primarily on problems and the negative factors which prevent or constrain certain actions. This is why I have chosen to add "opportunities and challenges" to the title for my paper. In many cases it is the constraints imposed on us which stimulate the opportunity and challenge for change and for the evaluation of alternative techniques.

Technical Factors

The lands vested in the Department of Conservation and Land Management (CALM) cover the full ecological spectrum; from wet sclerophyll tall forest to mallee, from coastal heaths to deserts. Much of the previous practical experience and research into fire behaviour was with the Forests Department, and was therefore restricted to the sclerophyllous tall forests of the south-west of the State, and to pine plantations.

Our current knowledge of fire behaviour in fuels such as heaths, mallees, tropical savannah and desert ecosystems is rudimentary and is based largely on the historical experiences of other organisations; for example the Bush Fire Board, Conservation Commission of the Northern Territory, National Parks, Fisheries and Wildlife, Shires and neighbours. Some research data was also available from Fisheries and Wildlife and National Parks staff, now incorporated in the new Department.

Table 1
Factors which need to be considered and may affect the implementation of proposed Fire Management Plans

FACTORS	TECHNICAL	ECOLOGICAL	IMPLICATIONS LEGAL	SOCIAL	ECONOMIC
Fire behaviour (eg, heaths and mallees)	✔				
Wind driven strips	✔				
Scrub rolling		✔			
Use of natural features	✔				
Helicopter and drip torches	✔				
Access				✔	
Bush Fire Act			✔		
CALM Act			✔		
Necessary Operations			✔		
Wildlife Conservation Act			✔		
Shire			✔	✔	
Friends of Parks				✔	
Neighbours				✔	
Dieback		✔			
Weeds		✔			
Flora - Protected - Declared Rare		✔	 ✔		
Fauna - Protected - Declared Rare		✔	 ✔		
Erosion		✔			
Visual impact			✔		
Chemicals		✔			
Burn Season		✔			
Burn Frequency		✔			
Burn Intensity		✔			
Firebreaks					✔
Staff numbers					✔

These experiences show that the use of fuel-reduced wind-driven buffers, fuel modification by chaining or scrub-rolling, the use of natural features in designing firebreak systems, the use of imagery to identify curing of grasslands, and the use of helicopters fitted with drip torches warrant closer investigation. This has commenced, but only recently. Nevertheless, these concepts offer exciting prospects for innovation, and evaluation of alternative procedures to those traditional for the forest areas.

Some fire research needs for heathland fuels have been proposed by L McCaw (pers comm). These are:

(a) classification, assessment and mapping of fuels;

(b) fire danger rating and fire behaviour predictions; and

(c) response of vegetation to fire regimes.

In addition, the system of fire weather forecasting has to be reviewed and a procedure for the capture of appropriate weather data for remote areas needs to be implemented.

Legal Aspects

The main legal requirements are contained in the Bush Fires Act, the CALM Act and the Wildlife Conservation Act. Of importance also is the approved Departmental Policy on Fire Management. This Policy sets out Departmental Objectives, Policies and Strategies.

Departmental objectives are:

1 To protect community and environmental values on lands managed by the Department from damage or destruction by wildfire.

2 To use fire as a management tool to achieve land management objectives, in accordance with designated land use priorities.

In relation to fire suppression, the Department will assess its response to a fire in the light of potential damage to the following values, in order of priority:

(a) human life;

(b) community assets, property or special values (including environmental values); and

(c) cost of suppression in relation to the values threatened.

Section 34 of the Bush Fires Act relates to Crown Lands other than State Forests and gives a neighbour permission to clear firebreaks and to burn Crown Land. However, if an approved fire management plan is gazetted, these powers no longer apply. In order to retain control of fire management practices on our land, a number of fire management plans for National Parks and Nature Reserves are being developed by CALM. Section 28 requires that fires be suppressed.

Section 33(3) and (4) of the CALM Act deal with Management Plans and Necessary Operations. Necessary Operations are defined as those necessary for the preservation or protection of persons, property, land, flora and fauna, or for the preparation of a management plan. Interpretations of what constitutes a "necessary operation" can differ. Guidelines and checklists need to be developed for Managers. Preparation of Interim Guidelines and Works Programs assist. Doubtful operations are referred to the Protection Branch and to the appropriate Director for a decision.

The Wildlife Conservation Act defines that most flora is protected (Section 23) and that some species are gazetted as rare (Section 23 F). In addition, all fauna is protected (Section 14) and some is given special protection [14 (ba)]. To cater for rare flora the Department has issued an approved Policy for the Conservation of Endangered Flora as well as a set of operational guidelines for field managers.

Ecological Factors

Important ecological considerations relate to dieback (a soil borne disease) and to aspects of prescribed burning such as season, frequency and intensity.

Dieback disease is spread by the movement of infected soil and root material. Its effects on susceptible species (such as heaths) in suitable sites (such as duplex soils) and in high rainfall areas can be devastating. The consequences of dieback on the vegetation, if the disease is spread by errors in planning or operations, can be far greater than the effects of fire itself.

When considering any operation, the disease status, risk, hazard, impact and consequences of disease spread on the vegetation must be evaluated. Various checklists such as the Seven-Way Test and the Pre-burn Checklist are available for field use.

The risk of spreading the disease during an operation can be reduced by:

Season

Operations should proceed only when seasonal conditions are against the fungus. Wet periods of the year must generally be regarded as high risk. *Phytophthora cinnamomi* reproduces rapidly during the warm and moist spring and autumn, but can also survive during the winter. Even in summer, moist gully environments provide suitable conditions for fungal survival.

Therefore any activity which involves the movement of moist soil represents a risk to the spread of dieback. Work should therefore be planned for dry soil conditions.

Obtaining Accurate Dieback Information

Where accurate, up-to-date, dieback-free maps exist for an area in question they should be used for planning a hygienic operation. In the absence of such maps the route must be checked, at least three months in advance. Inspection should be done by trained interpreters using indicator species (eg banksias, blackboys, patersonia) with sampling as required. Laboratory processing may take some time and samples should be despatched as soon as possible.

If possible the proposed works should be redirected to avoid dieback areas.

Hygiene

All dieback categories need to be demarcated. Operations should be confined to a single dieback category, and all equipment cleaned down when passing from suspect or known dieback infections into dieback-free areas.

Where dieback status is uncertain (eg absence of indicator species) activities should be confined to individual sub-catchments and all vehicles and plant cleaned down from one sub-catchment to the next and at the drainage line.

Prescribed Burning

Possibly one of the most controversial ecological questions relates to the season, frequency and intensity of prescribed burning. It is generally accepted that burning is carried out for legal and social reasons as well as for ecological needs. It is also recognised that burning for regeneration may be a requirement for the survival of some species. The preference for a mosaic of smaller burns, of varying season, frequency and intensity, alternating with unburnt areas, is often proposed as an acceptable ecological strategy. While this does create a mosaic of burning patterns and greater "edge" effects, there are also some disadvantages to be considered. These relate to higher cost, safety, access, firebreaks and the possibility for environmental damage through, for example, the greater opportunities for spread of dieback.

Economic Factors

In the current economic climate it is unrealistic to expect significant increases in either staff or money. Desirable changes will be achieved rather by the redirection of existing resources, or by cost-saving innovations. Concurrent with this cost squeeze is a political and public demand for less homogeneity in prescribed burning, greater public involvement and discussion.

To date, conservation lands have not usually been area prescribed burnt. Rather the emphasis has been on double (or triple) systems of firebreaks, with burnt buffers. This maximises the perimeter to area burnt. With the small staff numbers usually present at these fires, hopovers and escapes were frequent. In addition, some of our neighbours are not averse to dropping the odd match over the fence, once they consider that protected areas would and should burn, and the wind is blowing away from their boundary!

The existing system of firebreaks is extensive. In some individual Parks totals exceeding 400 or 500 kilometres are not uncommon. Maintenance is a problem in terms of costs, access and dieback control, weed invasion and erosion. An example of alternative solutions proposed for a Nature Reserve is given in Table 2.

Fuel modification by chaining, ignition by helicopter, alternative methods of constructing and maintaining firebreaks, wind-driven fuel-reduced buffers and area prescribed burning are being investigated as alternative ways of reducing costs and increasing efficiency.

Social Factors

The realities are that fire control and fire management must be implemented in a world where politicians, shire councils, neighbours, friends of Parks and the public have a definite stake and say in our activities.

This is recognised in the CALM Act, particularly in relation to public participation, as well as in the Departmental Fire Policy. This policy recognises the priority of life and property in guiding fire suppression activities. In addition, it stresses effective liaison with neighbours and commitment to improving public awareness through education.

Another aspect of significance is access. Firebreaks and management tracks required for fire control are not usually open to the public. Nevertheless they are often used and may open up access to environmentally sensitive areas, as well as to favoured fishing spots! The closure and subsequent upgrading and re-opening of some management access roads in National Parks along the South Coast Region was recently deemed necessary for the purposes of dieback protection. Though the program was generally well accepted, localised opposition did occur. Interestingly, while some fishing interests opposed the temporary closures, other parties (both fishing and wilderness interests) opposed the upgrading of tracks to a "safe" hygiene standard.

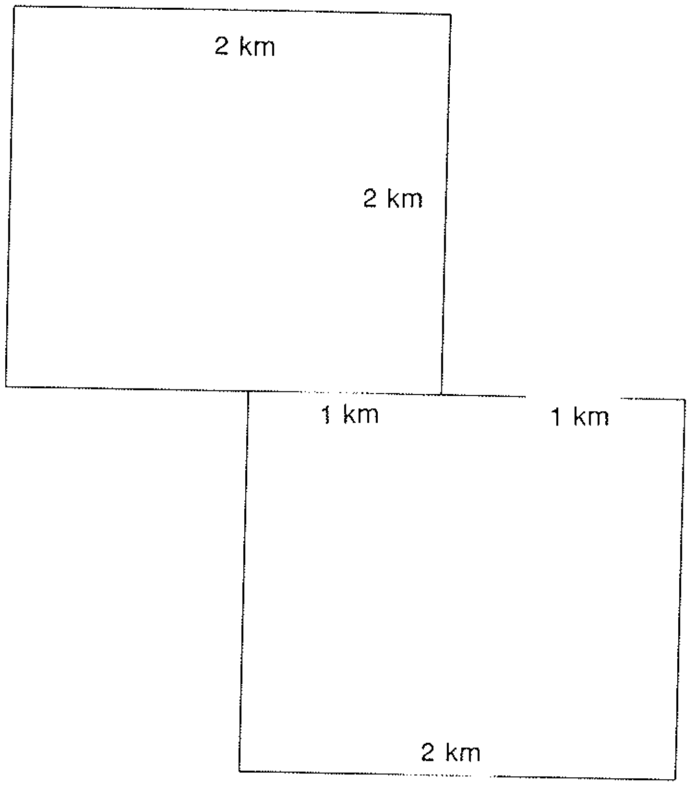
DISCUSSION

It is obvious that operational managers face many constraints and challenges in implementing CALM's fire management policies and plans "on the ground".

The role of the Services Branches (eg Research, Planning, Fire Protection, Environmental Protection), is to assist Operations staff. This can be done by providing data, resources (staff, equipment), suitable training, realistic policies and guidelines for operations.

In addition, these Branches assist in the development of Management Plans for Parks and Reserves. Where Management Plans will not be available for some time, Interim Guidelines and Annual Works Programs are developed by Operations staff in consultation with the Services Branches.

Table 2
Two Alternative Strategies for Protection of a Nature Reserve



		STRATEGY 1 (100m Buffers)	STRATEGY 2 (Blocks)
AREA OF RESERVE	(ha)	800	800
PERIMETER	(km)	14	14
FIREBREAKS	(km)	28	15
FIRELINE	(km)	28	8
AREA BURNT	(ha)	140	400
AREA/FIRELINE		5	50
BURN FREQUENCY	(yr)	0, 8, 16 etc	0, 4, 8, 12 etc

FIRE MANAGEMENT FOR CONSERVATION : PLANS AND PRACTICE IN A FIRE-PRONE ENVIRONMENT

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SUMMARY

Fires are a regular feature of the landscape in the wet-dry tropics of northern Australia. The fire season lasts throughout the "dry" from March-April until November-December. During this period more than 50 per cent of the woodlands and open forests are burnt by fires. Fire behaviour changes during the fire seasons. Fires early in the dry are smaller, more patchy, less intense and burn for shorter periods than fires later in the dry season. The ecological consequences of these fires also vary through the season.

Aims and methods of fire management programs vary depending on land use and the goals of a program. Where fire management is used for conservation goals, the major constraints of fire management fall into the following categories:

(a) ecological information on fire effects and the dynamics of species' reponses to fire;

(b) logistic constraints affecting burning strategies and fire suppression;

(c) economic constraints; and

(d) willingness to implement active or passive fire management practices.

In Kakadu National Park an active fire management program has been developed and implemented since its declaration in 1979. The major constraints on implementing this program are discussed in this paper, and data from fire reports analysed.

INTRODUCTION

Fires are a regular feature of the landscape in the wet-dry tropics of northern Australia. In the western Arnhem Land and Darwin regions fires occur annually throughout the dry season (Braithwaite and Estbergs 1985, Day 1985, Press 1987, 1988). The length of fire season is determined by the cessation and onset of the wet season rainfalls which Taylor and Tulloch (1985) have shown to be extremely variable. Unseasonal dry season rains (Taylor and Tulloch 1985) may also influence the fire season by suppressing fires, promoting growth, increasing fuel loads and allowing unseasonable germination.

During the fire season more than 50 per cent of the region's lowland woodlands and open forests are burnt by fire (Braithwaite and Estbergs 1985, Day 1985, Press 1987, 1988). Fires are also common on the Arnhem Land plateau and in coastal and floodplain areas (Day 1985, Press, unpublished analyses of Landsat imagery). Fire behaviour changes during the dry season and consequently fire effects vary. Braithwaite and Estbergs (1985) have shown that early dry season fires are smaller, more patchy, less intense, and burn for shorter periods than fires later in the dry season. Individual fires show great variability regardless of time of year (Hoare 1985, Gill *et al* 1980, Bell 1981, Mott and Andrew 1985, Press 1987, Hoare 1985).

A number of studies of fire behaviour and fire effects have been undertaken in the region. Some of the existing information on fire behaviour and fire effects in Kakadu National Park has been incorporated into a micro-computer based expert system (Davis *et al* 1986, 1987, Hoare *et al* 1986, Walker *et al* 1985), and a project to model vegetation responses to fire is under way (Noble and Moore 1987).

In this paper I will use the example of Kakadu National Park to discuss the implementation of fire management plans in a fire-prone environment.

Kakadu National Park Plan of Management

The Kakadu National Park Plan of Management (ANPWS 1986) specifically addresses fire management and provides for the use of fire as a management prescription (ANPWS 1986 pp 37-9). The Plan of Management states that, "The general aim of fire management is to re-establish so far as possible the traditional Aboriginal patterns of burning. This strategy also aims to reduce the frequency, extent and intensity of wildfire within the park and to protect species and habitats ... Fire management must allow for traditional Aboriginal burning practices ... In general fire management will be adjusted according to vegetation type and the existing status of the vegetation" (ANPWS 1986 p 39). The Plan of Management states also in relation to vegetation, "The main object of vegetation management is to maintain in perpetuity the natural diversity of plant communities and habitats, and to protect threatened plant communities" (ANPWS 1986 p 22); and in relation to fauna, "... to maintain the natural abundance and distribution of native animals and to identify the factors influencing the status of rare or endangered animal species ... the maintenance of habitats vital to fauna will be given high priority in Park management" (ANPWS 1986, p 30).

Aims, Methods and Constraints to Fire Management Plans

In practice the aims of a fire management program can be viewed on two levels:

(a) the primary aims (strategy, methods and implementation); and

(b) the biological (biotic) aims (short and long term consequences of adopting a strategy and the strategy and methods used to achieve a particular goal).

The implementation of a strategy to re-establish the presumed patterns of Aboriginal burning has implicit in it the primary goal of reducing the extent and frequency of late dry season wildfires which have been shown to have the greatest impact on vegetation structure (Hoare *et al* 1980, Bell 1981, Hoare 1985, Lacey

1985, Press 1987). In order to carry out this strategy it is necessary to adopt methods that are not those of the traditional Aborigines. Two hundred years ago there were between 2 000 and 3 000 people living in 23 clan groups spread over the region of Kakadu and surrounding lands. In 1987 there are only two to three hundred Aboriginal people living inside Kakadu, 1 500 people in Jabiru, about 50 Park staff in five locations, and two hotel complexes (ANPWS 1986). Fires are lit by Park staff on foot, from vehicles and by the use of aerial ignition (Day 1985, ANPWS 1986, Press 1987). These management fires are lit between April and July. The exact timing of the start and finish of these fires is dependent on rainfall, curing of fuel, and weather factors influencing fire behaviour. Fires after the end of June begin to be more uniform spatially and burn for longer periods of time (Hoare 1985, Braithwaite and Estbergs 1985, Press 1987, 1988). The majority of management fires occur in May and June, and the most wildfires in August, September and October (Figure 1). The number of recorded days for each fire increases during the fire season to peak in September and then falls off from October to December (Figure 2). Late dry season fires are more likely to have greater canopy scorch and ground cover removal than early dry season fires (Figures 3 and 4). These findings are consistent with those of other authors (Hoare *et al* 1980, Hoare 1985, Bell 1981, Braithwaite and Estbergs 1985).

The source of non-management fires ("Other" in Figure 1) are many: commercial buffalo catchers and pet-meaters; Aboriginal and non-Aboriginal residents; and visitors. Fires originating outside Kakadu National Park also account for many of the non-management fires (Day 1985, and unpublished analyses of Landsat imagery). Only a few fires in October, November and December are attributable to lightning.

Analyses of data from Landsat imagery (Day 1985, Press 1988 and unpublished data from 1986 and 1987) show that the extent of late dry season wildfire can be limited by early dry season prescribed burning. Therefore one stated aim of the Plan of Management - reduction in late dry season wildfire - can be met using management fires.

The constraints to implementing such a strategy are mainly logistic and economic. The period in which management fires are lit (usually May and June) is also the period when Park staff are gearing up for the pressures of the visitor season (in 1987 Kakadu National Park had an estimated 38 000 visitors in May and June). Fire management priorities must be met along with opening of campgrounds, establishing ranger-guided tours and early dry season maintenance and development activities. Both ground and aerial ignition are time and labour intensive. In particular, "precision burning" to protect sensitive habitats such as monsoon forest, or aesthetic considerations around campgrounds and visitor destinations take time and labour. Money must be available also for the provision of specialist equipment, supplies, aircraft hire, wages and overtime. In a large national park such as Kakadu (almost 20 000 square kilometres), vast areas are remote from roads or otherwise inaccessible, and this increases logistic problems and costs. Another constraint on the effectiveness of implementing a regime of early dry season ignitions is change in the sources and incidents of late dry season fires. Visitor numbers to Kakadu are increasing at a rate of 40 per cent per year, new or improved roads have made access to remote areas easier, thus increasing visitor numbers to these areas, and visitors are remaining longer in the Park. The township of Jabiru is expanding as are facilities at Cooinda and the South Alligator. The declaration of Kakadu Stage III over the Gimbat and Goodparla pastoral leases may result in increased visitation to these areas. Changes in the

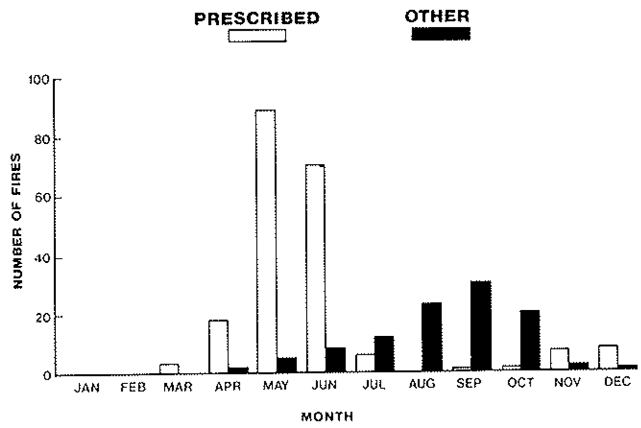

FIGURE 1
Sources of ignition. The number of fire report forms describing prescribed or other fires (wildfires, those lit by traditional owners, incursions from outside of Kakadu and others) for the years 1983-1986.

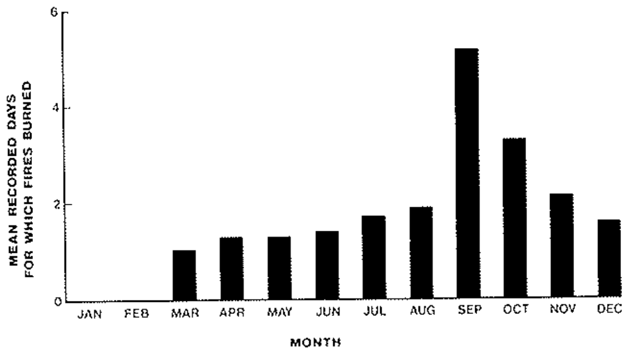

FIGURE 2
Length of fires. The means of the reported number of days for which each fire burned for the years 1979-1986. The variance of these means are as follows: Mar (s^2 = 1); Apr (1.59); May (1.57); Jun (1.91); Jul (2.89); Aug (3.6); Sep (27.80); Oct (15.6); Nov (7.11); Dec (5.6).

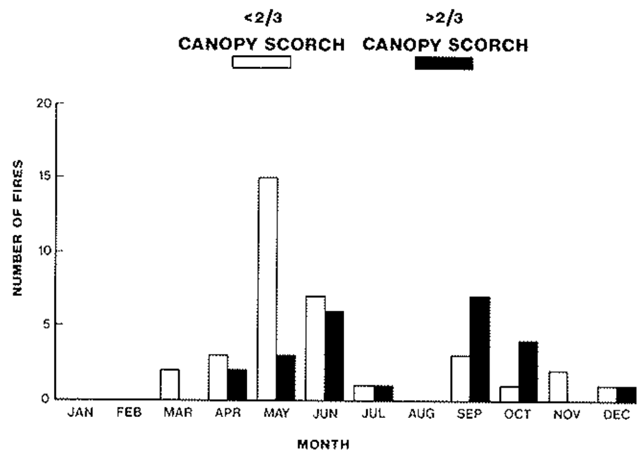

FIGURE 3
Canopy scorch. The number of reports estimating less than or greater than 2/3 of the canopy of foliage being scorched by fires during 1983-1986

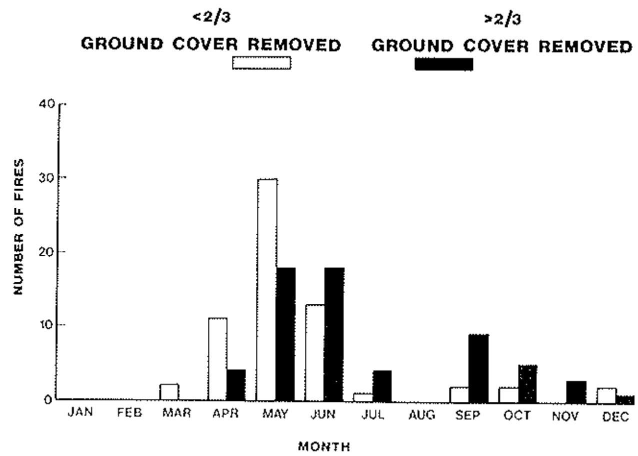

FIGURE 4
Ground cover removed. The number of reports estimating that less or greater than 2/3 of the ground cover had been removed by fire during 1983-1986.

demography and mobility of Aboriginal residents are also occurring. All of these changes may influence the success of the fire management strategy adopted for the region. Implementation of fire management programs is dependent also on the willingness of land managers to carry them out. This is especially so in relation to programs requiring the lighting of fires. Many European land managers in the "Top End" have a natural reticence, born of experiences in southern Australia, to go out and light fires. On the other hand laissez-faire attitudes to fire are also counterproductive to proper fire management.

Underlying the primary aims of any fire management program are the biotic goals. These are not usually explicitly expressed or if they are, expressed imprecisely. This is necessarily the case as in even a well studied national park the interactions between the biota and disturbances such as fire are poorly understood. Certain processes are obvious, for example repeated burning of entire monsoon forest thickets by wildfires will lead to their degradation and eventual elimination. The biotic goal of "preservation of monsoon forest thickets" can be met by elimination or reduction of the frequency of fires in monsoon forests. Other processes are not so obvious. The role of fire in *Eucalyptus* woodlands and open forests in the wet-dry tropics is disputed among ecologists (see Press 1987), and more empirical and experimental data need to be obtained before these processes are fully elucidated. Nonetheless, fire does have an appreciable impact on the structure of vegetation (Hoare *et al* 1980, Hoare 1985, Lacey 1985, Bell 1981, Press 1987). Hoare *et al* (1980) predicted degradation of forests if late dry season wildfires continued to dominate the landscape.

The Kakadu National Park Plan of Management requires protection of species and habitats and maintenance of the natural diversity of plant communities and habitats. This protection requires that this process of "degradation" be halted. The precise way to do this is unclear. First, it is obvious that a necessary condition is a reduction in the extent and frequency of late dry season fires (Hoare et al 1980, Hoare 1985, Bell 1981, Press 1987). What to do from this point onward poses many questions. Empirical evidence suggests two things:

(a) the absence of fire is not sufficient for recruitment to all strata; and

(b) the presence of fire *per se* is not sufficient to inhibit recruitment. Early dry season fires have less impact on recruitment than late dry season fires, and early dry season fires at intervals greater than one year have less impact than annual fires. The imposition of a static regime (eg early dry season fires) in all places may not be sufficient to reverse this process of "degradation". Historical changes in fire regimes (Hoare *et al* 1980, Hoare 1985, Braithwaite and Estbergs 1985, Press 1987) may have set in motion a series of processes which require more than just a simple reduction in the frequency of late dry season fires to ameliorate. Hoare *et al* 1980 and Braithwaite and Estbergs (1985) have described the absence of a mid-storey component in Top End forests. The management processes required to promote the establishment of this "missing stratum" could be quite complex.

Studies of the population dynamics of *Eucalyptus* forests in Kakadu National Park (Werner 1986), and simulations based on an extension of the Vital Attributes models of Noble and Slatyer (1980) have revealed fundamental gaps in the knowledge of "Top End" forests (Noble and Moore 1987). These gaps relate to propagule viability, time of seedling establishment, competitive interactions, environmental tolerances, growth rates between development stages, rates of senescence and the impact of different kinds of fires on the various life stages of individuals and species. Some of these data can be obtained by observation and others require manipulation and experimentation. Long-term experiments are necessary to elucidate the interactions between fire and fauna (Press 1987). While such large gaps exist in our knowledge, approaches to management must necessarily be conservative; ie to reduce the impact of disturbances (see Press 1987). The "fine tuning" of management plans necessarily is dependent on filling in these gaps in our knowledge.

In summary, the major constraints on the development and implementation of fire management plans are:

(a) ecological information on fire effects and the dynamics of species' (or communities) response to fire;

(b) logistic constraints affecting burning strategies (and fire suppression);

(c) economic constraints; and

(d) willingness to implement active or passive fire management practices.

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APPENDIX 1
SOURCE OF DATA FOR FIGURES

Data used in Figures 1-4 are derived from fire report forms completed by staff of Kakadu National Park. These data have inherent biases which should be considered:

(a) the first report form has changed a number of times since 1980 and some data were not included on some of these forms;

(b) observations are biased by accessibility to the source of ignition or to fires themselves;

(c) fires may have burned for a number of days without being observed (see Figure 2);

(d) the estimates of scorch height and patchiness are purely subjective and not quantitative. The >2/3, <2/3 categories are arbitrary;

(e) some data have been excluded because they were incomplete;

(f) it is likely that a greater proportion of management-lit fires were reported than wildfires.

OPERATIONAL CONSIDERATIONS AND CONSTRAINTS TO IMPLEMENTING FIRE MANAGEMENT PLANS IN SOUTH WEST TASMANIA

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SUMMARY

Conflicts over the use of fire will inevitably arise between specific fire management objectives such as the protection of life and property and various ecological considerations. Fire management planning is the resolution of these conflicting demands and the formation of operational programs to achieve these goals. South-West Tasmania is inaccessible and contains large areas of wilderness. It is generally wet with fire exclusion communities often abutting more pyrogenic and often fire promoting communities.

The recognition of constraints is vital in allowing operational programs to be implemented. Such constraints in South West Tasmania include the limited access by any means other than helicopter and walking, detection of fires, limited resource knowledge, erodible peats and soils, fire exclusion communities abutting pyrogenic vegetation, unreliable weather forecasting, lack of studies on fire behaviour and the accumulation rates of fuels, the presence of *Phytophthora cinnamomi* , inadequate communication facilities and social pressures brought to bear by conservation interests and industry.

INTRODUCTION

Fire has been a part of the ecology of South-Western Tasmania for many thousands of years. There is evidence to suggest that fire has played a key role in the development of the present pattern of vegetation (Jackson 1968, Brown and Podger 1982). This pattern is remarkable due to the juxtaposition of pyrogenic vegetation (*Gymnoschoenus sphaerocephalus*) and fire sensitive communities which have remained unburnt for many thousands of years. Such communities include ancient King Billy pine (*Athrotaxis selaginoides*) forests and alpine heathlands.

The task of managing fire in an area such as the Western Tasmania World Heritage Area (WHA) National Parks is not an easy one and must embrace compromise from the desired goals to allow for the many and varying practical and operational constraints which occur.

Fire can be a potentially positive biological agent as well as a destructive one. The orange bellied parrot (*Neophema chrysogaster*) is a prime example of a species with a fire induced habitat (Brown and Wilson 1984). Without the younger vegetation to form a suitable food base, the species could not survive.

The destructive force of fire is well documented and is the main concern of fire management planning. In the last 20 years, 16 per cent of Tasmanian alpine vegetation and 8 per cent of Tasmanian rainforest, both of which are fire sensitive communities, have been burnt in wildfires (Brown *et al* 1983, Kirkpatrick and Dickinson 1984). Prevention of the destruction of climax communities containing rare species and habitats is the prime concern of fire management planning in south west Tasmania.

Background Resource Information

The Western Tasmanian WHA National Parks fall within the forty-one to forty-four degree latitudinal band which is characterised by moist rain bearing westerly winds for most of the year. Orographic lifting on the mountain ranges within the parks leads to rainfalls in excess of 3 000 mm in many areas (Bureau of Meteorology 1987).

Geologically, the southern and central parts of the WHA are dominated by white quartzitic peaks that rise above valleys cut into softer rocks such as schist and dolomite. Angular dolerite peaks dominate the northern region. The parks boast large areas of karst which host many caves and underground drainage systems. Characteristic of the area is the peat that covers many of the valley floors and slopes. This peat has an average depth of 30 cm but can be as deep as three metres.

A wide range of vegetation communities representing different seral stages exist within the WHA. The positioning of these seral stages leads to the principle point of conjecture among researchers and managers: whether site factors give rise to a vegetation type with a stable fire frequency (The Mount School; Mount 1979), or whether chance shifts in fire frequency will change vegetation and site factors, one fire acting as a contagion point in a Poisson type distribution (The Jackson School; Jackson 1968). The implications for fire management are profound; either fire frequencies are constant and a function of sites (resulting in stable vegetation boundaries), or fire frequencies are capable of change and hence altering vegetation patterns.

One of the reasons for the nomination of the region as a World Heritage Area is its large wilderness component (Australian Heritage Commission 1981). The parks contain few roads and only a sparse network of walking tracks. Whilst this may make fire management more difficult, one aim of fire management must be to retain the area as wilderness with minimal permanent disturbance.

Past Fire Management

Past fire management within the WHA can be divided into three broad periods : pre 1960, 1960 to 1970 and since 1970. This division can be attributed to society's changing attitude toward the use of fire and the acceptance of the area as an asset in its own right. Different departments have managed the area with different goals in fire management and variable resources at their disposal to carry out fire management objectives.

Before the 1960s there was no conscious policy as the area was not considered an asset (apart from being a source of huon pine and possibly minerals), and there was little peripheral development being undertaken. This period saw many thousands of hectares of alpine herbfields, native conifer forest and rainforest destroyed due to deliberate lighting of fire and the lack of understanding of the effects of these fires.

The period from 1960 to 1970 saw the beginning of the broad acre burning period. Forestry and mining activities were beginning to take place within and around the area that required protection from wildfire. Broad acre burning was assumed to be the answer and was carried out whenever funds and weather permitted. Little active suppression was undertaken.

The formation of the National Parks and Wildlife Service in 1971 and subsequent extensions of the area under its care saw a "minimum area burnt" policy being introduced. The natural values of the area were being understood and appreciated more, but there was still no real understanding of the dynamic processes involved. A general policy of minimal area burnt was undertaken until a better understanding of the dynamic processes of fire ecology and fuel dynamics could be gained.

Current Fire Management Planning and Policy

The statement of objectives of park management should form the basis of fire management and planning. Specific park objectives for state reserves in the WHA include:

(a) maintaining a long term fire regime where native plant communities presently represented are able to regenerate;

(b) maintaining plant communities in some areas at seral stages which optimise the available habitat for rare animals with known habitat preferences; and

(c) maintaining an element of chance so that the natural processes of seral progression and ecological drift can, in the long term, express themselves in terms of community composition and fire regime (Rando 1985).

Conflicts inevitably arise between specific goals, particularly the protection of life and property and conservation goals. Fire management planning is the resolution of these conflicting objectives on the basis of the best available information at the time of decision. Policy must be made on the basis of those actions which it is believed will best achieve the stated objectives. Critical to this process is the use of the best available biological and social data, and the constant monitoring of actions to ensure that they are directed towards the attainment of the desired objectives. Several research programs are underway at present to complement existing information and to widen the existing data base on which information can be drawn to make specific decisions.

There are four main choices in strategies for fire management: suppress all fires; allow prescribed burns in certain areas; allow natural fires to burn in specified areas; or allow all fires to burn (Fischer 1984).

The fourth alternative is unacceptable because of its adverse biological, social and economic implications. Combinations of the first three have been used by the National Parks and Wildlife Service at different times and locations. The answer as to what is the most appropriate for South West Tasmania is derived from the management objectives, the known fire history and the implications of different fire regimes to the perceived values to be protected.

The Department of Lands, Parks and Wildlife (successor to the National Parks and Wildlife Service) fire management policy is currently under review. This document describes how fire can be used and gives long term protection of the ecosystem priority over any management activities, including the use of earth-moving machinery, which may cause long term environmental degradation.

Fire management planning is close to completion for the three WHA National Parks and peripheral areas to the west. The process of fire management planning is by no means perfect, but attempts to address the constraints placed upon managers through a system of zoning the land, according to the known assets, into parcels. These parcels are composed of similar ecosystems, have common special features or have similar use considerations or similar fire situations. Common fire management objectives, and therefore prescriptions, can be applied to these zones (Fischer 1984).

These fire management zones reflect the four basic responses to fire: fire suppression, observation, scheduled prescribed fire, and conditional fire management.

Operational Considerations and Constraints to Fire Management Planning

For a fire management plan to be acceptable, the implementation or prescription section must be operational. The plan must be able to come to grips with real constraints, yet try and achieve the desired aim. Identification of these constraints is vital, allowing solutions to be designed and management actions implemented to take account of the constraints. Constraints and considerations that apply to South-West Tasmania can be broken down into several categories, each of which is discussed below.

Physical Constraints

The three National Parks that make up the WHA occupy close to 770 000 ha. The size and the remoteness of the area mean that fire management planning has to recognise that response time will be at best several hours. Access to the area is limited, helicopters being the only reliable method of transport except for walking. There are several small airstrips within the parks and several more on the periphery allowing some fixed-wing aerial access. The Lyell Highway transects the parks and is the only major road access. Several other small tracks give access to the perimeter and a small percentage of land within the parks.

Any suppression action that is undertaken has to allow for a time lag in operations, the expense of the operation, and the availability of a limited number of helicopters in Tasmania. (Two helicopters were brought in from Victoria for the Mulcahy Bay fire in December 1986 due to the shortage of local helicopters. The time delay in getting these helicopters to Tasmania may have meant the difference between being able to suppress the fire and failing to stop it.)

The Western Tasmania National Parks were inscribed on the World Heritage List in 1983 for their wilderness values amongst other reasons (Australian Heritage Commission 1981). These internationally recognised values must be considered when any management action is being undertaken. No track or trail construction will take place and fire line construction must be kept to a minimum and only used when necessary for the protection of life and property. The long term environmental degradation associated with any track construction may be decidedly worse than the effects of the fire due to highly erodible soils, peat, and the high rainfall. This in turn means that natural boundaries are used where possible, direct attack will be used where safe, and that some fires may not be extinguished until the fire nears a suitable natural boundary or until it rains.

Vegetation

The vegetation pattern in South-West Tasmania presents its own unique set of problems to the fire manager. Peaks rise to altitudes of 1 000 m and contain unique alpine vegetation and rainforests unburnt for many hundreds of years. The surrounding valleys and ridges contain pyrogenic vegetation. Fire sensitive communities often abut fire promoting communities. Due to the risk of fires running into fire sensitive communities and at the least causing edge attrition, fuel reduction burning is considered too likely to cause damage. It will not be carried out on a broad acre basis until fire behaviour and fuel dynamics are better understood, and the risk of damage to fire sensitive communities is significantly reduced.

Weather

The weather in South-West Tasmania is predominantly under the influence of moist rain bearing westerly winds. There are two main scenarios which can produce days of high fire danger:

(a) a blocking high which directs a warm and dry northerly air flow of mainland origin over the state; and

(b) a south-westerly airstream that is not particuarly warm but has a very low relative humidity. This second possibility is particularly hard to forecast reliably as there are no meteorological stations west of Tasmania. In many parts of mainland Australia, a cold front can be tracked as it passes through towns and accurate predictions of its speeds calculated. A much closer watch has to be kept on the visible weather patterns when dealing with fires in South- West Tasmania.

Resource Information

To date, no detailed resource surveys have been undertaken for the whole WHA. Specific resource data are available for selected sites and for selected communities. Aerial photography is only available at 1:42 000 black and white and there is no detailed vegetation or community mapping for the whole of the area. Aerial photography is planned to be carried out at 1:25 000 in colour during the 1987-88 summer.

The lack of resource information and reliable vegetation/community mapping hampers efforts to detail species and communities which require protection from fire. The lack of information not only compromises the planning of species protection but can obstruct suppression efforts. In most cases the rate of spread and predicted fire path is only known in vague terms due to the lack of specific vegetation mapping which would allow such fire path prediction.

Fire Behaviour

Few studies have been carried out in Tasmania on fire behaviour, especially in buttongrass moorlands. Before accurate predictions on fire behaviour can be made, studies of fuel accumulation rates, effects of slope and wind on the rate of spread, species composition and the amount of available fuel under different moisture regimes need to be undertaken.

The lack of reliable fire behaviour guidelines is one reason the Department considers fuel reduction burning a risk to existing vegetation assets. Fire may also become uncontrolled due to lack of suitable boundaries. Where fuel reduction burning is undertaken for specific site protection, studies are simultaneously undertaken to improve information on fire behaviour and fuel dynamics.

Disease

South-West Tasmania is fortunate with regard to the spread of *Phytophthora cinnamomi* in that access is poor and consequently the spread of fungal spores in infected soil is minimised. *P. cinnamomi* has been recorded in areas where there has been previous soil disturbance. Fire is thought to accelerate the spread of the fungus by increasing solar insolation to the soil through the removal of vegetation. Any use of hazard reduction burning must be carried out in full consideration of the need to restrict the spread of the fungus.

Current fire fighting practices involve handtools and hose lays with transportation of personnel and equipment by helicopter and boat. The risk of spreading *P. cinnamomi* whilst using these techniques is low. All tools are washed down with a suitable fungicide after use.

Communications

Base to mobile and mobile to base two-way radio communications within much of the planning area are poor. A limited remote base station network exists mainly on the perimeters of the parks. The lack of effective communications can hamper suppression efforts or the implementation of management actions. The siting of manual relay stations on nearby mountain ranges to give effective ground-to-ground and ground-to-air communications may be necessary.

Single side band HF radios are used when fighting remote fires in conjunction with the Hobart Radio "Radphone" service. This allows fire to Head Office communications when necessary. This form of communication is not reliable as the distance between sites is often not suitable for the use of HF band radio.

The department is currently planning to upgrade the radio network but is restricted by the requirement not to develop mountain tops for remote radio base stations.

Detection

Detection of fires in South-West Tasmania can be a somewhat opportunistic business. Residents at Melaleuca (a remote mining settlement on the south coast), mining exploration camps, tourist charter flights, fishing boats and yachts, bushwalkers and the general public in the case of the Lyell Highway have all been responsible for passing on information to the Department about fires. The Department also runs a fire spotter flight over much of the area on days of high fire danger.

Due to the large and remote nature of the parks, fires will usually be past the initial spot fire stage before the Department can act on a fire report. The fire may be too large to attempt direct suppression.

Human Error

Human error will always be present whether we like it or not; however, there have been far too many escaped "controlled burns" in Tasmania. A portion of the native King Billy pine (*Athrotaxis selaginoides*) stand at Lake Rhona, a high altitude tarn in the Denison Ranges, was destroyed as a result of such an escape. Strict guidelines on how fire is going to be used and prescriptions for each individual operation must be prepared to minimise the risk of human error.

Social Pressure

South-West Tasmania is an area unique in Australia for its cool temperate rainforests, its large wilderness area and the rare species and habitats it contains. As such, there are many people who are concerned with how the area is managed. Pressures are brought to bear from industry with economic viewpoints and from conservation groups concerned with the protection of the environment.

Community pressure can be considered a benefit as it ensures management activities are carried out with proper planning. However, problems do arise as different people have different expectations on the use of fire. All view points must be taken into consideration when planning the use of fire and the rationale explained in each case.

Resources

One of the main constraints on the implementation of the current fire management plans is that the Department has limited resources, both human and financial to carry out fire suppression operations. Attempts will nearly always be made to suppress peat fires due to their ability to burn for long periods, igniting vegetation when conditions are suitable. Such attempts can cost $10 000 per day to extinguish with only twenty people. These fires characteristically take several weeks to extinguish. The entire fire suppression budget for one year can be consumed in one fire. Casual staff are often employed in fire suppression activities but the time delay in getting a crew of casual staff together is in the order of twenty-four hours. The recently established Government Trust Fund for wildfire suppression has helped alleviate the monetary problem.

Future Directions in Fire Management

The recognition of constraints in achieving a desired goal is vital in allowing operations to be carried out efficiently. Many of the constraints that have been identified and discussed within this document can be alleviated by the appropriate allocation of resources.

The need for reliable fire behaviour guidelines, resource information and data on fuel accumulation rates is mentioned throughout this report; these are vital information requirements for effective fire management. In May 1987, a seminar was held between all fire managers and researchers to determine the current research priorities of departments interested in fire management and to co-ordinate future directions in fire research. The priorities that were established for fire research for better fire management are listed in Eberhard (1987). These findings form the basis of the Department's research program for the next decade.

The findings were categorised into several sections and the top priorities in each section are:

Ecological Research

- effect of fire on sedgeland animals
- fire refuges in sedgelands
- historical and archaeological evidence of past fire events and past fire regimes.

Fire Studies

- fuel accumulation rates in sedgelands
- guidelines to fuel characteristics in Western Tasmania.

Inventory and Mapping

- mapping rare species and special habitats in the WHA
- mapping principal vegetation types in the WHA from colour aerial photography.

Management Studies

- management requirements of rare vascular plants in the WHA

- management requirements of the ground parrot, *Pezoporus wallicus* in the WHA.

Effective radio communications are a vital component of any fire suppression action. Sites for remote base stations in the VHF band have been selected to complement existing sites. These stations will be developed subject to funding and Departmental policy on development of remote sites. Improvements in technology and the gradual increase in coverage of the area mean that communications will become more efficient. A communications plan is being prepared to oversee the development of the radio network.

P. cinnamomi is a fungus that has already destroyed many thousands of hectares of native vegetation Australia-wide. A program of mapping the existence of the fungus and research into the effects of fire spreading the fungus may eventually improve to management practices which hinder the spread of the disease.

Of all the requirements needed to improve fire management, funding is the common thread. Research into better equipment, radio communications, resource data bases, disease, soil erosion, fire behaviour and fuel accumulation rates all require considerable sums of money. The rate of improvement in practices and equipment is directly related to the funding of the various departments involved with fire in Tasmania and in other States.

CONCLUSION

Fire management planning is an important process for not only understanding the natural role of fire in different ecosystems, but in detailing operational programs designed to implement Departmental policy with regard to fire management and fire suppression. Inherent in putting most plans into action, are operational considerations and constraints which must be taken into account. The identification of these constraints is an important step in making plans become reality as efficiently as possible. Once identified, these constraints can be rectified and allowed for where possible. The rate of development of new equipment and information is highly dependent on the level of funding.

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MONITORING FOR FIRE MANAGEMENT IN NATURAL AREAS IN WESTERN AUSTRALIA

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SUMMARY

This paper provides a brief outline of key aspects of the monitoring program soon to be implemented within the Department of Conservation and Land Management. This program is designed to provide for gradual improvement in management of Departmental lands by improving the knowledge base on which decisions are made. It is anticipated that monitoring will be an important part of fire management in the future.

INTRODUCTION

The rationale for a monitoring program within a land management agency such as the Department of Conservation and Land Management has been provided in earlier papers presented at this National Workshop. Three important, contributing factors can be summarised thus:

1 There is a dearth of reliable information about the effects of fire on most of the species of plants and animals, and communities and ecosystems that we manage. Further, it is unlikely that research resources will be sufficient to remedy this situation in the forseeable future.

2 At the same time there is a need to make decisions on the management of the biota, particularly in relation to the use of fire on conservation lands, because of concerns about protection. Decisions not to burn (ie the do-nothing option) are included here.

3 There is, therefore, an urgent need to establish a mechanism whereby the knowledge base can be improved through the process of management - to learn from successes and mistakes and to ensure that mistakes are not repeated.

These sorts of considerations are equally relevant to virtually every type of management issue on natural lands.

It was the recognition of the need to develop a mechanism or process whereby management could be improved by systematically recording effects of ongoing management that led the Department of Conservation and Land Management, in February 1988, to adopt a policy on monitoring. This policy is now in the process of being implemented through the establishment of a monitoring program within the Department and through the development of pilot projects throughout the State.

The monitoring policy deals with all aspects of management including planning and development of management policy. However, it is likely that, in the process of implementing the policy, fire will feature prominently amongst the pilot projects because of its pre-eminence as a management issue in Western Australia.

Here I discuss some key aspects of the policy and program in order to introduce them. A more detailed description is given in Hopkins (in press).

Objectives of the Monitoring Program

As noted above, the monitoring program is seen as an important vehicle leading to improved management of Departmental lands (and waters) and of the State's biota. The improvement will be a consequence of the following:

- Monitoring increases the level of knowledge about the resources being managed.
- The program provides a framework for making better management decisions based on the ever-improving knowledge base and on regular review.
- The implementation of management decisions becomes more accountable and will improve as a consequence.
- The monitoring program provides a focus for co-operative activity throughout the Department and with the wider community; this leads to more effective and efficient use of Departmental resources.

The specific objectives of the monitoring program are to maintain up-to-date records of the distribution and status of the State's biota, the management decisions that are made about that biota and Departmental lands and the consequences of those decisions, and to provide a mechanism for systematically reviewing management policies and programs in the light of new information.

Key Features of the Monitoring Program

Because monitoring is essentially a field based activity associated with management, there is a tendency to focus on procedures to be used in the field. However, it is important to recognise that the field component cannot function in isolation; the monitoring program has to embrace a range of activities from data management through to review of results, policies and management programs. In designing the program to meet the objectives outlined above and to cover the wide range of activities necessary, particular attention was also paid to generating strong user interest in order to ensure long-term continuity of observations. Cost effectiveness was also a major consideration.

Data Management

In order to learn from past decisions and actions it is necessary to maintain adequate records of those decisions and actions. The first essential function, therefore, is archival. Secondly, it is necessary to have a streamlined method for dealing with field data. The automated data processing system should incorporate a user-feedback component with two types of prompts. Prior to the sampling time falling due there should be a reminder about the need for sampling which may include a request to observe particular features. Once the new data are input a hard copy record should be sent to the observer with a thank you and a comment on the new data.

Field Recording

All observations are based around fixed points each of which has a unique identity. The most basic level of recording involves standardised photographs. However, there are some very serious limitations to the use of photographs. In particular, photographs do not readily yield quantitative data. It may be possible to overcome this drawback through the use of stereo-photography. The Department is currently evaluating a Micro-photogrammetric System (MPS-2) which can accept 35 mm slides and which is computerised; the system could be used in some circumstances to produce quantitative data from monitoring sites.

An early step in implementing the monitoring program will be the preparation of a Field Monitoring Procedures Manual. This will outline in detail the actual steps to be taken to establish a monitoring site and to record appropriate information at that site. A question and answer type key to aid in the selection of methods is also envisaged.

One critical aspect of each monitoring project will be the clear definition of objectives. In many cases the objective will be stated as an hypothesis to be tested. The importance of the clearly stated objective is three-fold. Firstly, it is essential for communication - new observers must be able to readily understand what it is that they are contributing to. Secondly, it facilitates selection of field sampling methods. Thirdly, it provides a more scientific basis for each project and the program as a whole; thus, monitoring can be seen to be a legitimate scientific activity.

Responsibility for doing the actual field recording will lie with local management staff. This makes sense from the efficiency point of view since these are the people on-site; it also fosters a sense of ownership. The local management staff may choose to liaise with specialist staff (eg research) when setting up a new site or project but prime responsibility will be with managers. The only clear exception will be in the case of those sites to be surveyed comprehensively on a regular (if infrequent) basis as biological benchmarks. This comprehensive survey will be done by specialist survey staff.

Management Planning

During the course of preparing management plans for natural areas, planning staff invariably identify areas of uncertainty or critical gaps in knowledge. Where a monitoring program exists, planners can move beyond mere identification of problem areas. They can allocate priorities for information gathering and should collaborate with research and management staff to design monitoring projects to address gaps.

Review

It is essential that the data, once collected, are put to best use. The monitoring program provides for regular review of results from each monitoring project and publication of the outcome of the review. By bringing the results to the attention of decision-makers in this way it is expected that review of management policy, strategies and programs will flow more or less automatically.

CONCLUDING REMARKS

The Departmental Monitoring Program which I have outlined briefly in this paper is an important innovation in the management of natural lands because it provides an economic means to gradually improve the quality of management. It will be used to improve fire management, particularly in those biomes that have been little-studied to date, because of the pre-eminence of fire as a management issue throughout the State.

The Monitoring Program is still in its infancy. As it stands at present, it is the result of several years of reading and discussion and small scale trials. There are many aspects yet to be developed in detail; then the program has to be put into practice on a reasonable scale. Undoubtedly there will be some changes in the course of implementation; as problems come to light then corrective action will be taken. It is for this reason that the approach being taken is one of gradual implementation.

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MONITORING FIRE-PRONE FLORA IN RESERVES FOR NATURE CONSERVATION

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SUMMARY

Monitoring is an important component of scientific management. It is the process of repeated assessment of the condition of a resource which, in this case, is the complement of vascular plant species of a conservation reserve. In this paper, monitoring is seen to be a process constrained in practice by the availability of staff, time and money and, therefore, one to be implemented in a minimal set of reserves, at a minimal set of sites, on a minimal set of species, for a minimal period of time for a minimal set of attributes. Reserves for priority monitoring are those with greatest departures from naturalness while sites for monitoring within reserves are here considered to be a minimal set chosen from those surveyed with restrictions made according to recent fire history, species composition and species responses to fires. Monitoring can be further reduced by choosing to assess a species at only one site although it may occur at many. The consequences of choices of sites and species are explored using minimal data set theory across a spectrum of circumstances varying from complete ignorance to moderate, but incomplete, knowledge. Every monitoring event should be a learning event so that as time proceeds there is even less to monitor. As an example, the available data for Nadgee Nature Reserve in south eastern New South Wales have been collated then analysed. It was assumed that the purpose of monitoring was to reveal the regenerative status of all plant species present so that planned fires may be initiated, or unplanned fires suppressed, according to current species condition. A total of 201 sites had been surveyed but only 72 were needed to incorporate all recorded plant species (601) at least once. For monitoring, only species with unknown regenerative mechanisms or longevity, and perennials with non-vegetative recovery mechanisms were considered; 389 species remained. Using only the "monitoring species", 65 sites were needed to record all of them at least once. The need for further work due to absence of data on one hand, and the tentative nature of much of the remainder on the other, is stressed.

INTRODUCTION

The world literature on the monitoring of vegetation in conservation areas is minuscule. Possible reasons for this are that monitoring is seen to be: an informal function of normal managerial action and not a topic needing research attention;

an unnecessary action for conservation reserves with natural ecosystems; a practice too difficult to implement; or, a program too expensive to run in terms of staff, finance and time. In this paper, the need for monitoring within the context of a scientific management program is explored and ideas for the design of a monitoring system in which costs are to be minimised are presented.

Scientific Management

A rational program for the implementation of scientific management in a conservation reserve will consist of the following elements:

(a) the establishment of aims and goals;

(b) an assessment of the resource (inventory and survey);

(c) a consideration of managerial problems and the operational tools to overcome them;

(d) the implementation of management; and

(e) the monitoring of the resource in terms of the aims of management.

For the purpose of this contribution, the aim of management is considered to be the maintenance of the total pool of vascular plants in a reserve in perpetuity. Other possible aims such as the extermination of alien species, the preservation of scenic beauty and historic relics, the maintenance of vegetation structure, the persistence of animal communities and the enhancement of recreational opportunity are not considered here despite the fact that they are of practical importance in many cases.

For many managers of Australian conservation reserves the major problem of management is, primarily, the control of unplanned fires, and secondly, the long-term biological consequences of measures taken to minimise the frequency, intensity and extent of such fires. The manager has a range of techniques suited to the solution of the problem such as prescribed fire and suppression strategies. If the manager knows the condition of the flora under his care - through monitoring - he can make decisions to prescribe fire or not, or to assign priorities for suppression operations to particular areas with confidence. In this paper, then, the need for, and the design of, a monitoring program is considered within the fire context. It is assumed, for current purposes only, that the problem is one of too frequent fires rather than one of an absence of fire and, as such, the manager has no need to consider the possibility of local extinctions due to the absence of fire.

Inventory, survey and monitoring are related. Inventories (check lists) represent the first step from ignorance towards knowledge. Surveys, which consist of site-specific data (of plant species lists in this case) represent another forward advance, but their completeness is a measure of the degree of advancement toward complete knowledge of the resource. Because monitoring is a process of checking or repeated assessment of condition, it relies on a knowledge base; an item cannot be monitored if it is not known that it exists. Australian conservation reserves have few inventories, fewer surveys and no formal systems of monitoring in place.

It could be asserted that monitoring is not necessary because natural ecosystems are self perpetuating. This may be the case but it is arguable that vegetation of any conservation reserve in Australia is in a completely natural state. Firstly, reserves often have artificial boundaries, and include roads, survey lines, even prospecting activity; secondly, reserves usually have introduced plants (including fungal diseases) and animals present; thirdly, reserves usually have changed fire regimes due to an historical shift from Aboriginal to European management and the changed cirumstances in the landscapes around reserves (eg farming) which affect ignition rates and extent of spread of fires; and, fourthly, changes may occur in regional water tables and salinity due to agriculture or urbanisation in areas around the reserve. It is a matter of observation that many reserves are greatly disturbed and not at all natural.

The Monitoring Problem

The monitoring "problem" is seen here to be one of too many reserves with too many items to monitor with too few staff, too little money and too little time (after Gill 1986). The "solution" then is to choose, by establishing priorities, a minimal set of reserves (eg on the basis of lack of naturalness), a minimal number of sites within a reserve, and a minimal set of items to monitor for a minimal period of time. The establishment of detailed priorities for the monitoring of named reserves is not considered here but, in general, the reserves most open to artificial influences - whether from management or other sources - may be given greatest priority. Thus, small reserves near cities set in agricultural contexts may be chosen first while large remote reserves may be given lowest priority. Most attention is given below to the questions relating to the numbers of sites to be monitored, the numbers of plant species to monitor, the period of time for which to monitor, and the attributes of species which should be observed.

Monitoring may be seen as a process through which knowledge grows. As a consequence, the intensity and purpose of monitoring should change through time. If everything is known, monitoring is unnecessary; if nothing is known, inventory and survey are needed first. Monitoring, then, is a process which is most effective when knowledge is incomplete, a ubiquitous circumstance in Australian conservation reserves. Thus, this study utilises incomplete data bases.

Minimal Sites

Preliminary analyses have been carried out on a data set consisting of presences and absences of plant species for 201 sites in Nadgee Nature Reserve in south eastern New South Wales (NSW). A map of the vegetation is given by Fox (1978). The sites were chosen originally as trapping sites for small mammals (30 sites) and as track-identification sites for animals (or "sand plots", 106 sites). The remainder were chosen by Gilmour (1983) as part of a vegetation survey (65 sites). Different plot sizes were used to assess the floristic composition of the vegetation, plots being 400 m2 for the sand plots, 700 m2 for the mammal survey (PC Catling, personal communication) and dimensionless for the vegetation survey (Gilmour 1983). The vegetation varied from wet sclerophyll forest to heath and included floristic elements as diverse as *Atriplex, Callitris, Ficus* and *Cyathea*. Two severe fires have swept the area in the past fifteen years, one in

1972 (Fox 1978) and one in 1980. The area has been relatively well studied particularly in relation to animals, heathlands and fires (eg Newsome *et al* 1975, Recher *et al* 1975, Fox 1978, Posamantier *et al* 1981). The data-set chosen was considered to represent the current state of knowledge of the floristics of this relatively well-known reserve and to be typical of the most likely way that site-specific data banks will accumulate for nature conservation reserves in general.

After cross-referencing the species lists for synonyms with the help of floras (Beadle *et al* 1976, Burbidge and Gray 1970, Willis 1962, 1972) and a checklist for NSW (Jacobs and Pickard 1981) they were subject to minimal common set analysis (Margules *et al* 1988). This analysis chooses the minimal number of sites, from all those available, which collectively include all species of the total set. Having achieved this with the total data set - the current state of knowledge - the numbers of sites available for analysis were randomly reduced to indicate the consequences of having a poorer data base on which to work. With fewer sites sampled, of course, there would be fewer species known to occur on the reserve. Four runs of the analyses were made to indicate the variation expected with a different sequence of sites being dropped in each series.

The analyses (Figure 1) show that of the 201 sites recorded, only 72 were needed to record all species. As the number of sites available decreased, so too did the minimal number of sites to just include all species. When only eleven sites were left, all were needed to represent the species complement. However, with only eleven sites the number of species present was down to between 169 and 290 out of the original 601 (Figure 1b). Extrapolation of Figure 1b suggests that further survey will reveal further species so the number of sites for a minimal set will grow.

If any of the sites of the data set are not fire prone they can be "removed" from the list for the purposes of monitoring described earlier. To decide fire proneness, any site which burned in either of the severe fires of 1972 and 1980 was included while any site which was untouched by both events was considered not to be fire prone. Of the 201 sites, only three were unburned in either 1972 or 1980. The elimination of these three sites reduced the size of the minimal data set to 71 sites (Table 1) and 578 species. Note that only one of the three sites not fire prone had been included by the minimal common set analysis.

Table 1
Numbers of observations of presence (i.e. the sum of species numbers for all sites) which would be required in a monitoring program of the 201 recorded sites at Nadgee Nature Reserve, NSW, given the criteria shown.

Criteria	Number of Sites	Number of Species	Number of Observations of Presence
1. All sites and species	201	601	7257
2. All species, minimum sites	72	601	2798
3. Minimum sites, minus non-fired sites	71	578	2674
4. As for (3) above but species observed once only	71	578	578
5. As for (3) above but for species other than ferns, annuals, biennials and known vegetative regenerators	65	389	1431
6. As for (5) above but species observed only once	65	389	389

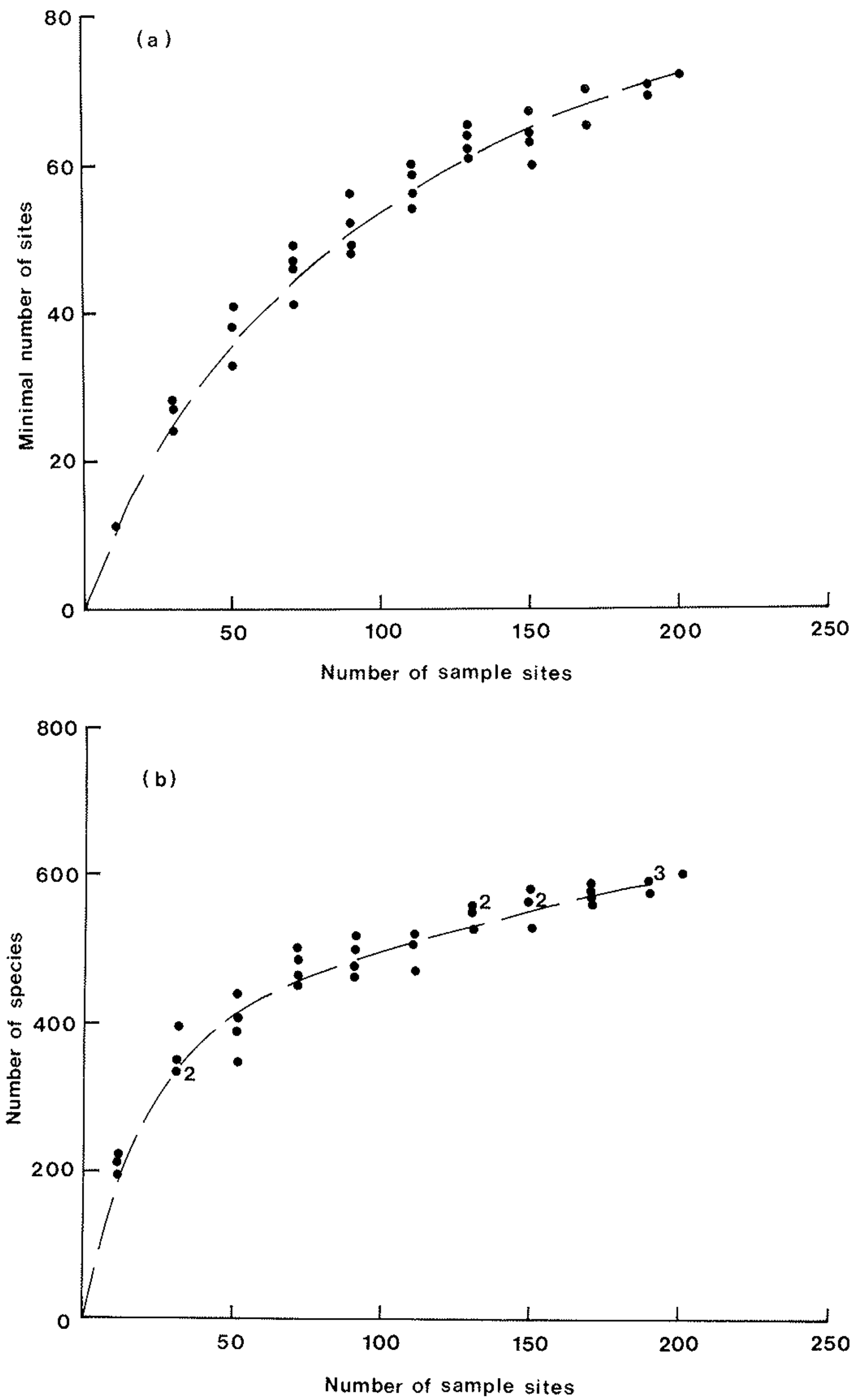

FIGURE 1
Analysis of data from plant species surveys for Nadgee Nature Reserve, NSW, to show the effect of random deletions of sites from the 201 presently recorded on (a) the minimal number of sites necessary to record each species at least once; and (b) the number of species present in the data set. The dashed lines were fitted by eye.

Minimal Species

A priority for species monitoring can be established on the basis of what is known of plant species responses to fires in general and what is known of the responses of those species in the data set in particular; ie we can give priority to those species we regard as being the most vulnerable to local extinction and those for which we have no information. To achieve this priority we can follow the path of selective elimination of species from the data set, according to current knowledge, until only the most vulnerable class is left along with those with unknown properties.

Consider that a severe fire has passed through the whole reserve (as it did in 1972). What we may expect is the early appearance of some annuals, some biennials and some fire ephemerals which we can assume will set seed within a short time and, therefore, be able to persist beyond a further fire. We can drop these species from the monitoring program. Other species will have various mechanisms of vegetative recovery such that most of the original population will survive or, if regenerating from spreading rhizomes, stolons or roots, even expand their populations; these species may be regarded as relatively secure. However, such species should not be regarded as totally secure in all circumstances because frequent repeated fires can decimate their populations (Grano 1970), sometimes (as in the case of mallee eucalypts), in an interaction with season of fire occurrence (Noble *et al* 1984). Also likely to be secure are ferns which have such light propagules, *viz* spores, that their return to a site, even if fire sensitive, seems assured. There is very little information available on the fire responses of ferns, however.

In this analysis, if a species often recovers vegetatively but a large proportion of the population has been observed to die in severe fires, (such as the *Cassia eremophila* A Cunn ex Vogel of the semi arid region, Wilson and Mulham 1979), then it should remain in the monitoring set for the time being. In following this particular step-wise process of elimination, we would expect to eliminate vascular plants in a series from those with very short primary juvenile periods such as annuals and some fire ephemerals, through to biennials and further fire ephemerals then to species with secondary juvenile periods (ie the time from the fire to first flowering in vegetatively regenerating plants, Gill 1975) which are mostly short also. Many vegetatively regenerating woody species begin to flower two or three years after fire.

Using the floras for the Australian Capital Territory (Burbidge and Gray 1970), the Sydney region (Beadle *et al* 1976) and Victoria (Willis 1962, 1972) each species was assigned its appropriate classification for life cycle (annual, biennial, perennial) and origin (native, alien) where recorded. If not specifically stated, an "unknown" designation was applied. Fire responses were assigned, where known, on the basis of personal observations or observations of those who have worked in similar vegetation types elsewhere along the New South Wales and Victorian coasts. If different observers found different responses for the same species in different areas then the species was retained as one for monitoring. It is important to note that the information obtained is not the result of deliberate systematic observation of species responses at Nadgee but is from scattered geographic sources and from casual observation at Nadgee and elsewhere (see Table 2 for details). Perhaps, like the site-specific species lists, this is the way information is gradually compiled by managers and, as such, is typical of the information is gradually compiled by managers and, as such, is typical of the limited data available to a reserve manager. We emphasise that our purpose here is to illustrate how such a data base can be used to assist in the design of a monitoring program.

The results from Nadgee (Table 2) reveal a considerable level of ignorance in relation to longevity and fire responses. Of the native species, a very large proportion were perennials of which most were species which regenerate vegetatively after fire. A quarter of the aliens were annuals or biennials whereas only about three per cent of native species occurred in these categories. If ferns, annuals, biennials and the vegetative regenerators among the perennials are overlooked for the purposes of monitoring then the species data set is reduced by about one third.

Table 2
Numbers of species in various longevity, fire-persistence and origin classes for the Nadgee Nature Reserve species list. Observations of fire-persistence were made by various people at various locations: *viz*, the senior author at Nadgee and on the southern tablelands of NSW; DH Benson (1985) near Sydney; M Fox (personal communication) at Myall Lakes National Park, NSW; F Ingwersen (1977) at Jervis Bay Nature Reserve; P Stricker (personal communication) at Royal National Park, NSW; and M Wark *et al.* (1987) near Angelsea, Victoria.

Species class	Natives	Aliens	Unknown origin	Total
Ferns	41	0	2	43
Annuals	15	6	1	22
Biennials	3	2	0	5
Perennials with				
• vegetative regeneration	122	3	0	125
• seed only regeneration	68	5	0	73
• unknown responses	234	9	7	250
Longevity unknown, not ferns	69	5	9	83

Minimal Time, Minimal Attributes

By tackling which attributes of a species should be priority monitored, the minimal time for monitoring can be assessed. There are two aspects to this. Firstly, there is the time spent at a site on each occasion when monitoring. Secondly, there is the duration of years over which monitoring should take place.

The time spent in monitoring the desired attributes of a population will depend on some inherent characteristics of that population. Monitoring a species with high ground cover and many individuals would be much more efficient than monitoring one with a very low cover and a few individuals only. Thus, in setting up a monitoring program it may be desirable to choose sites where a species is obvious, if possible, rather than those where it is obscure. This is something we have not been able to take into account here because of the absence of information.

By recording some measure of performance, such as abundance or cover, the observer may not only discover trends but also know whether or not the species is going to be hard to detect. For small plants, abundance and cover are going to be related but for big plants, like mature trees, a few individuals may provide a high cover. Because big plants are going to be more fire resistant than small plants of the same species in most cases, and because the recording of big plants as having one individual in a plot is not very meaningful, it is considered that the single best estimate of vegetative performance is cover. A cover value has the most information content for the time spent in its determination; an ocular estimate of percentage cover or an assessment of a species as having "low", "medium" or "high" cover may be sufficient.

While the most pertinent reproductive measure to record may be seed production, such a conclusion raises the difficulty of how frequently monitoring should be carried out within a year because of the variation between species in reproductive phenology. No systematic information is available for Nadgee Nature Reserve but for the perennials being considered here it is likely that flowering takes place for most species in spring while fruit maturation may cover a much longer period of time. So, while seed production may be the most pertinent measure to record, flowering is considered to be the more practical because not only is its appearance more likely to be confined in time than fruit development, its presence assists in the detection of uncommon species and the flowers themselves are diagnostic for species identification.

In pursuing a minimal number of species to monitor, various species were dropped from the program at the outset because they were considered to be more tolerant of fires than the remainder. As monitoring proceeds, however, further species could be dropped from the program on the basis that their regenerative status had become adequate to ensure their persistence in the event of another fire occurrence. To explore the question, then, of the duration in years that a species should be monitored, attention is focussed on what is perhaps the group of plants most vulnerable to extinction, viz fire-sensitive shrubs with seed held only on the plant, and not at all in the soil.

It is a matter of simple logic that a fire-sensitive species without a seed store in the soil cannot survive two fires within the juvenile period of the species at that site unless unburned mature specimens remain nearby to disperse seed onto the site. The minimum requirement for survival of such species, then, is that the juvenile period be exceeded without fire.

While no data are available for Nadgee species, juvenile periods for some fire sensitive species in the sclerophyllous vegetation on nutrient-poor sandstone of the Sydney region have been recorded (Benson 1985). Half of the 33 species examined in the Sydney region had juvenile periods of four to five years as assessed by observations on tagged seedlings but precocious plants of the same species nearby had juvenile periods of only one to three years. The longest juvenile periods of six to nine years were found in seven species but these periods varied somewhat between sites. Two of the species in the Sydney study also occur at Nadgee, viz *Xanthosia tridentata* DC with a juvenile period of six years and *Hakea teretifolia* (Salisb) J Britt with a juvenile period of seven.

The behaviour of species in the Sydney area or elsewhere provides a guide to behaviour at the particular site for investigation, but caution in interpretation is necessary. For example, while *H. teretifolia* had a maximum observed juvenile period of seven years at Sydney (Benson 1985), the species at Nadgee eight years after fire had abundant seed, perhaps an unlikely occurrence for the first year after flowering, and also showed substantial fire resistance with up to 70 per cent of stems resprouting (AM Gill, personal observation). In Benson's (1985) study the minimum juvenile period of *H. teretifolia* was six years for tagged specimens but as little as two years for precocious plants. There may thus be considerable variation in behaviour within and between populations.

Fire sensitive species burned soon after their first flowering will have little regeneration post-fire because not all flowering in the first year leads to fruit production (Benson 1985, Wark *et al* 1987), fruit maturation may take a year, relatively few plants may set seed initially, and many years may be necessary before seed production is sufficient to restore the population after a fire (Gill and McMahon 1986). Given that it is desirable for a suitable seed store to be built up for regeneration before further burning takes place, monitoring may continue until this is observed or, alternatively, certain rules-of-thumb may be followed as a practical approach to management, not only for species whose seed store can be observed on the plant, but for all species.

Two rules-of-thumb are that seed production will be adequate when 50 per cent or more of the plants present have become reproductive (Van Wilgen 1980), or when a number of years has elapsed that is at least equal to twice the juvenile period observed. (These two guidelines are not mutually exclusive because the determination of the juvenile period will depend on a certain proportion of the plants first flowering rather than on the behaviour of isolated precocious plants.)

Research on a fire sensitive shrub with canopy-stored seed in north western Victoria, and south eastern South Australia, *Banksia ornata* F Muell, has shown that the species there has a juvenile period of five to seven years (Specht *et al* 1958, Figure 1; Gill and McMahon 1986). The time to more than 50 per cent of the population flowering was between seven and eleven years and the estimated time for sufficient seed to be accumulated to reproduce the population - given certain qualifications - was sixteen years (Gill and McMahon 1986). From this isolated example, doubling the juvenile period (eight to fourteen years) gave a more appropriate result than the time to 50 per cent of the population being reproductive (seven to eleven years).

Until further data become available it is suggested that a doubling of the general juvenile period of the species observed at the monitoring site be used as the guide to when the species is likely to be able to replace itself to prefire abundance levels. Of course, exceptions are to be expected.

Practical Monitoring

One further step remains in the sequential investigation into a monitoring scheme for the flora of a nature conservation area. To recapitulate previous steps: firstly, the number of surveyed sites necessary to just include all species at least once was determined; secondly, a number of steps were followed to reduce monitoring sites and species to a minimum, viz by considering only fire-prone sites, only one site per species, and only the most vulnerable species or those with unknown sensitivities; and, thirdly, a minimal number of attributes to be recorded for a minimal time was suggested. As a result of the second series of steps the "minimum number of sites" determined by the first step can be further reduced. Therefore, a second minimal common set analysis was conducted on the initial Nadgee data set with three sites removed because they were considered not to be fire prone, with all ferns, annuals and biennials removed, and with all fire-resistant perennials removed. The result was that of the 201 sites of the original surveys only 65 needed to be monitored according to the rules adopted here; 389 species were present (Table 1, Figure 2).

While the task of monitoring for plant species appears large for Nadgee as outlined here with 389 species-observations to be made for cover and flowering (equal to twice the number of species-observations) in the early years after fire, in practice a manager setting up a monitoring scheme would initially spend time assessing fire response types so as to reduce the numbers of species to consider in his monitoring program. Furthermore, it is unlikely that the manager would always be faced with monitoring the whole of the fire-prone portion of the reserve as assumed here because, in practice, only burned areas would receive attention and such areas are often only a portion of the fire-prone area. If canopies of trees were not killed, the species represented would not be monitored and, as species reached their juvenile periods - which are mostly short - monitoring of these species would cease. As monitoring observations decreased, the manager may pay more attention to the accumulating fuel quantity and the chances of fire in relation to the "vulnerable" period for the community - which can be defined as double the juvenile period of the species with the longest juvenile period. The manager may find that conservation groups could relieve him of some of the monitoring activity.

Practical issues like how to record, store and retrieve the data have not been considered here. For research purposes, photographs have proven particularly useful in some cases such as at Koonamoore Vegetation Reserve in South Australia (Hall *et al* 1964) and in Kosciusko National Park in New South Wales (Wimbush and Costin 1979). Hopkins *et al* (1987) have included photo points in their general monitoring system for reserves in Western Australia.

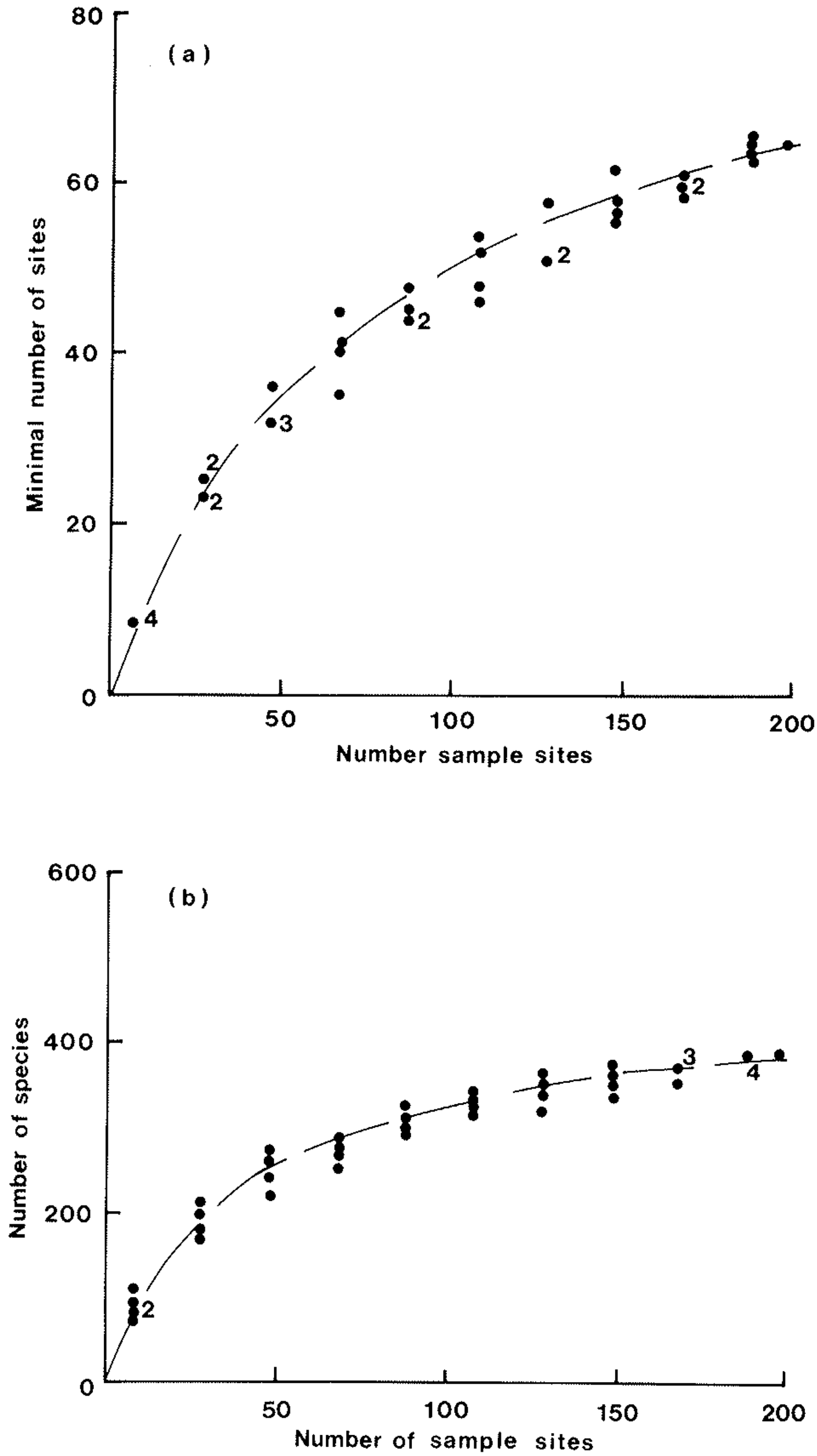

FIGURE 2
Analysis of data from plant species surveys for Nadgee Nature Reserve, NSW, to show the effect of random deletions of sites from the 198 fire-prone sites present when species are excluded from monitoring according to longevity, life cycle and vegetative persistence through a fire event: (a) on the minimal number of sites necessary to record each species at least once; and (b) on the number of species present in the data set.

DISCUSSION

The manager may wish to monitor many other ecosystem components than the floristic one. Structural features of plant communities, numbers of animals and extent of erosion are a few of the many possibilities. Each of these may be regarded as a target for monitoring (Gill 1982) in that the process is aimed at a particular component of the environment. Another aspect of monitoring is to continually look for unexpected changes in non-target components; comparing sequential images from remote sensing devices is an example.

In this contribution we have used minimal common data set analysis for determining the number of sites at which monitoring should take place. The method also had value in pointing to the need for further survey. Use of such analyses for the design of monitoring programs can be an on-going procedure as different combinations of sites are affected by unplanned or management fires from time to time.

Only the simplest of classifications of fire responses was used here due to the general lack of information. It has rudiments of the classification of Gill (1981) and lacks the relative sophistication of the classification of Noble and Slatyer (1980) which requires a knowledge of conditions of establishment (tolerant/intolerant) and critical life stages (time to reproductive maturity, longevity of the species population and the time to reach local extinction - including soil-stored seed) as well as the method of persistence through a fire event. A computer package designed to assist observers to record fire responses of plant species has been written by Noble (1985) using an "expert system" approach. The sequence used here to eliminate species from the monitoring program is not necessarily one that would be universally chosen. However, it does reflect the process envisaged for the design of a monitoring program. Species considered to have a high certainty of survival were eliminated from the program while those of uncertain or potentially vulnerable status were retained. The sequence used may be different in other areas, eg where season-of-burning may have an important effect.

No special attention was given to alien species in the analysis. However, many managers may wish to monitor such populations carefully in order to devise ways of controlling their growth and spread.

The methods used here could be incorporated into the various systems of geographical data basing and process modelling that are becoming more and more widely used in Australian landscapes (Kessell *et al* 1980, Davis *et al* 1985, Thackway *et al* 1985). These systems already include ways of recording fire events and site data such as species lists. The addition of a monitoring subroutine to these packages would augment their value.

CONCLUSION

Monitoring is rarely practised in Australian conservation reserves. Part of the reason for this is that too few staff, too little money and too little time are available. The methods presented here should enable managers to design a cost-efficient strategy for the monitoring of plant species persistence in perpetuity given sequences of either unplanned or management fires. Perhaps the greatest need in many reserves is for a survey of the flora and determination of the way species persist through a fire event. Monitoring will then reveal critical periods such as the times to first flowering and seed set.

ACKNOWLEDGEMENTS

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MONITORING THE EFFECTS OF FIRE MANAGEMENT ON NATURE CONSERVATION VALUES

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SUMMARY

The effects of managers on nature conservation values, through either the alteration of fire regimes or as a result of the methods used to manage fire, can be substantial. Monitoring is necessary to identify the environmental effects, ascertain whether the objectives of management are being achieved, and decide what adjustments by managers might be necessary to achieve the objectives. It may lead to changing the management strategies and, in some cases, the objectives of management, should these prove to be unrealistic.

Successful monitoring requires clear objectives, cost effective methods, adequate resources and motivation. Some approaches towards practical and meaningful ways of monitoring are outlined for vegetation, wildlife, soils nutrition and hydrological and wilderness values.

INTRODUCTION

To monitor is to "observe critically" (Oxford Dictionary). Here it is taken to mean the systematic recording and evaluation of changes over time to provide guidelines for management.

Monitoring is necessary to assess what effects land managers have on the environment, whether the objectives of management are being achieved and what adjustments by managers might be necessary to help achieve the objectives. The adjustments would normally involve changing the management strategies, but if the objectives were shown to be unrealistic then these also would need to be changed.

Management of fire is undertaken in most conservation reserves, although the emphasis has been more on suppression of fire than its use for ecological purposes. Changes to the fire regime are a consequence of management, leading to fire exclusion in some areas and, at the other extreme, to frequently repeated or unseasonal burning in other areas. This directly affects flora and fauna, favourably or unfavourably, depending on the fire regime imposed and the species or community involved (Gill *et al* 1981). Altering fire frequency, for example, can alter vegetation composition and structure and wildlife distribution, and decrease soil fertility (particularly nitrogen). The effects may be critical in small or fragmented reserves where there is limited resilience to major distrubance or change, and limited scope for recolonisation of species from other areas.

The methods and associated facilities used to control or manage fires can also significantly affect nature conservation values. These include:

(a) site disturbance by machinery affecting soil, vegetation recovery, spread of weeds and soil borne diseases and wildlife survival;

(b) increased access degrading wilderness values, increasing visitor activity and impact, and creating habitat fragmentation and barriers to some fauna;

(c) constructed water storages supporting animals foreign to the area, including pest species; and

(d) fire retardants and polutants from machinery altering soil nutrient levels and affecting vegetation.

The effect of managers, through either the alteration of fire regimes or as a result of the methods used to manage fire, can be substantial and therefore require monitoring. There has been relatively little such monitoring in Australia, and the challenge is to develop practical and meaningful ways of doing this.

Successful monitoring relies on having a clear understanding of management objectives, cost effective monitoring methods and motivated people (Campbell 1987).

Management Objectives and Strategies for Fire Management to be Considered in a Monitoring Program

For conservation reserves, the objectives are generally the protection and maintenance of natural ecosystems, life processes and flora and fauna. There may be more specific objectives such as the promotion of particular plant or animal species or the maintenance of wilderness values. Another common objective is the protection from damage by fire of human life and property, either in the conservation reserve itself or in adjoining areas.

Strategies developed to achieve these objectives may include:

(a) burning for ecological purposes, such as habitat manipulation to promote a range of seral stages or favour specific species, and to regenerate or rehabilitate particular plant communities;

(b) fuel reduction by burning, grazing or mechanical means; and

(c) wildfire suppression to restrict uncontrolled spread, ranging from attempted total exclusion of fire to permitting wildfires to burn in remote or wilderness areas where human life or property is not threatened.

Cost Effective Monitoring Methods

Effective monitoring relies on selecting the critical aspects and parameters to be monitored, developing practical and meaningful ways to monitor (which others could undertake and are likely to continue in your absence) and evaluating the results to provide feed-back so that managers may if necessary adjust their programs.

The aspects that may be monitored are numerous and will vary according to the situation or project under consideration. These in broad terms include fire history or the fire regime itself; effects of wildfires, fuel reduction or prescribed burning for ecological purposes; and effects of fire management works and facilities.

Techniques for Monitoring

Techniques may be qualitative or quantitative, using direct records made on site or remote sensing techniques such as multispectral imagery. Although a quantitative approach will provide more detail and precision, it is generally more costly and time consuming and may not be warranted if a suitable qualitative approach is available, such as photographic plots to record general vegetation changes. Multispectral satellite or airborne imagery and computerised programs for image analysis (eg MICROBRIAN) are undergoing rapid technological development and offer increasing potential for monitoring fire events and vegetation changes, particularly on the broad scale.

Some Approaches to Monitoring

In the case of *prescribed burning*, a monitoring program (whether basic to assess the successful conduct of the operation, or more specific to determine responses of particular species or communities to the fire) should entail making records both before and after the event. Before and after event data for a given site are much more meaningful than the comparison of matched events on different sites. For wildfires, unless studies already happened to be in progress, pre-fire data are generally not available. To improve the availability of pre-fire data, all research or inventory plots should as far as possible be accurately marked both on the ground and on maps. This may entail relatively little effort and could be a bonus later for monitoring.

Following any fire there should be an initial assessment or monitoring program, which may lead to monitoring over a longer term. The basic short term approach recommended is to:

(a) Map the extent of the fire and any major unburnt islands which may be important refuges. Aerial photography or satellite imagery can be useful to achieve this for large fires.

(b) Identify specific areas of unusual fire frequency (eg burnt by successive fires in a short period) or not burnt for a very long period which have value for close study and protection.

(c) Assess monitoring requirements to assist management (eg sites of biological significance to be monitored for recovery; grazing animals inhibiting vegetation regeneration, such as rabbits grazing *Callitris preissii* (Cheal 1982); rehabilitation of earthworks and vegetation clearance resulting from fire suppression work).

Some vital considerations or guidelines concerning the aspects and parameters to be monitored are as follows:

Vegetation changes

- record of species composition and vegetation structure changes are basic to understanding fire ecology and management priorities, ie what is the desired fire regime.

- if possible select indicator species for study, representing different strategies of regeneration, sensitivity to disturbance, health and vigour of vegetation.

- assess whether variety is being promoted, whether selected species are being favoured and weeds invading.

- be aware of what is being measured, eg interaction between drought, frost and fire; between fire and grazing or carnivorous animals; or between fire and man-made disturbance.

- evaluate effects of different firebreak construction methods and soil rehabilitation methods, or effects of chemical fire retardants on vegetation recovery.

- assess effect of earthmoving equipment as an agent for the introduction and spread of soil borne plant pathogens (eg *Phytophthora*) and weeds.

Wildlife

- similar principles to monitoring vegetation apply to wildlife.

- species presence is relevant, but ability to feed and breed in the area are the critical determinants for survival.

- long lived species or species with selective breeding requirements (eg parrots (Burbidge 1985), Malleefowl (Benshemesh 1986)) are of highest monitoring priority because lack of recruitment may not be apparent until too late unless it is monitored.

- loss of tree hollow habitat due to fires is an incremental process and may not be evident unless it is monitored. Fires may also help create hollows.

- artificial water supplies in arid areas can affect species distribution of birds and attract pest animals (Williams 1986) and extend the distribution of feral bees; these aspects warrant monitoring.

Soils, Nutrition and Hydrology

- soil movement and sedimentation measurements can indicate losses in site fertility, sedimentation of streams and changes in stream substrate affecting microfauna.

- soil nitrogen levels generally are most limiting to plant growth (Tartowski 1986); large potential nitrogen losses occur after fire which can be monitored in terms of little biomass burnt, and the recovery will be dependent on re-establishment of nitrogen fixing legumes, lichens, algae and soil microfauna (Hopmans 1987).

- monitoring may be needed to assess increased run-off and stream flow patterns, and changes to watercourses, swamps or bogs due to burning of peat or high organic accumulations.

Wilderness Values and Site Amenity

- the effect of increased access (constructed for fire management) on wilderness values, as well as on changing visitor activity and their impact on site, and the fragmentation of habitat is an important aspect for monitoring.

Some general guidelines apply to all aspects of monitoring. A standardised format for recording like data is advocated as this aids later analysis and provides compatability with data collected from other areas, thereby enabling the pooling of data and its wider use.

A successful monitoring program requires a scheduling system to ensure measurements continue to be made at the prescribed times and a definite end point. It is also essential that data are analysed progressively and conclusions are drawn and heeded.

Movitated People to Undertake the Monitoring

If there is clear understanding and acceptance of the management objectives and monitoring goals, and if the monitoring program is cost effective (readily carried out and useful) then it is likely that motivation for monitoring will be correspondingly high. However, unless Departmental priorities for monitoring are high the resources available for monitoring will limit achievements regardless of the calibre of the program and motivation.

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SOCIAL FACTORS AND PUBLIC INVOLVEMENT IN THE PLANNING PROCESS

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INTRODUCTION

Land management authorities throughout Australia spend millions of dollars on the technical aspects of fire control, but like many other areas of land management fail to recognise the importance of social and political factors which can influence the implementation of fire management strategies. As important and difficult as the problems associated with the technical side of fire management are, social factors can nevertheless be far more important. It is of little purpose to develop a comprehensive fire management strategy for a particular area of land if the implementation of that strategy is prevented because the managers failed to take notice of social and political constraints.

Land managers usually have a training in science and consequently fail to appreciate the complexity and difficulty of first assessing the social and political factors, and then developing strategies to deal with them.

No-one can deny the legitimacy or importance of the social and political factors in fire management. Public lands are managed usually by State authorities, but on behalf of the public. Failure to recognise that the public has a role to play in determining the uses of the land which are managed on their behalf ignores the basic premise on which management of public lands is based.

Deficiencies in Our Approach to Understanding Social Factors

It must be recognised that the vast majority of the Australian public is not the least bit concerned with the approach that land management authorities take to fire management of natural ecosystems. This does not mean, however, that there is not a place for public involvement in fire management. Rightly or wrongly, a minority group in the community objects strongly to the type of fire management regimes that are currently practised by land management agencies, at least in Western Australia. Why is this so?

Divisions between technical decisions and policy decisions are not clear-cut.

One of the problems between land management and fire management in particular is that decisions regarding the impact of fire on vegetation have value and technical components which are not distinguishable. For example, in the medical profession there is a legitimate area for value judgements to be made by the general public on such questions as whether invitro-fertilisation is an appropriate method of inducing pregnancy. However, nobody in the community questions the techniques used by the specialised surgeon in carrying out invitro-fertilisation. In contrast, the fire manager is confronted with people in the community questioning, for example, the technical basis of spring and autumn burning. It is quite appropriate for members of the community to voice their opinion through the planning process, or through their elected members of Parliament, their desire for a particular type of vegetation in a particular area. The difficulty comes when members of the community impose, or attempt to impose, their opinions on the techniques which are used to achieve this objective.

The community has difficulty in interpreting complex scientific data.

Too often land managers ignore the complexity of the problems associated with the implementation of different fire regimes. Scientists working in a specialised area very quickly develop their own vocabulary, which makes it difficult for a non member of that scientific community to understand the rationale for different burning regimes. This problem exists even amongst people who work in associated areas; so how can we expect an ordinary member of the community to develop a rational view of a particular burning regime?

Common to both the community and members of land management agencies is an inability to look at the total picture of any particular land management practice. Consequently, the alternative lifestyle - cabin owner in the southern forest - looks only at the area surrounding his block and bewails the fact that it has to be burnt. Whereas, those who are responsible for the total area have to take cognisance of a master burning plan to protect that particular person as well as other members of the community.

A separation exists between those who are making decisions and the people responsible for implementing them.

One of the difficulties that land managers face, and particularly those associated with fire management, is that members of the community who desire to influence the fire management policies do not have to bear the consequences of that decision. For example, it is relatively easy for members of an advisory committee giving advice on development of a fire regime for a national park to make decisions which they perceive are designed to favour the conservation of flora and fauna without regard to the consequences of that policy on the safety of recreators in the same park.

There is a lack of trust.

One of the principal reasons for divisions between members of the community and those responsible for implementing fire management strategies is an historic lack of trust between the bureaucrats and the community. This polarisation is evident, not only between the State authorities and community groups, but between different groups of farmers and between farmers and increasingly alternative lifestyle people who move into rural areas.

Solutions

There is no magic format for resolution of the problems between the community's opinion of fire management regimes and those who are responsible for managing our public lands and imposing those regimes. There are, however, a few basic approaches which can be used.

Recognition of the importance and inevitability of public involvement

Many fire managers have failed to recognise that it is inevitable that the public will be increasingly involved in determining fire management policies. In the past, it has been possible to carry out whatever burning regime is perceived to be necessary without reference to the public. Those days are gone. It is important that we recognise the public will be involved and develop techniques to handle that public involvement.

Communication

Given the inevitability of public involvement in determining fire management policies, it is important that scientists and fire managers inform the public of the reasons why the type of fire regime is being imposed. Too often we devote ourselves, in the case of scientists, to the production of scientific publications which are read by relatively few, or fail to communicate at all to community groups. Communication is a difficult and complex process because there are many different types of groups that are interested in fire management, varying on the one hand from farmers, and on the other to conservation groups. This means that we must use as many avenues of communication as possible and not be afraid to repeat our message over and over again.

Objectives and policies

It is important that the objectives and policies of the Government are clearly defined. For example, it is the responsibility of government to determine, in the extreme situation, whether in fact life and property has a lower priority than conservation values.

Involving the public

One of the most important management techniques is to ensure that those who are involved in formulating policy have ownership of that policy. This technique ensures that:

(a) The community accepts some responsibility for the types of policies that they require. For example, in the case of a national park, if an advisory committee insists on a burning strategy which does involve some risk to human life, their tendency to take the extreme position will be modified.

(b) The very process of involvement of the public reduces the polarisation which underlies much of the antagonism concerning our burning policies.

Finally, I believe that it is possible to develop burning regimes which accommodate most of the requirements of the general community. However, it is also important for the community to recognise that accommodating the community requirements involves a cost.

Managers, in recognition of this, must give it an appropriate priority and at the same time ensure that the community clearly informs the ultimate arbiters, the Government, that it does cost more but that it does want the additional degree of sophistication brought with it.

A PERSPECTIVE ON PEOPLE AND CONFLICT IN LAND MANAGEMENT PLANNING

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SUMMARY

The transformation of concern for the environment into political issues has led to the establishment of Public and Corporate Conservation Agencies. While focusing their attention on biophysical issues, many such agencies have neglected to come to terms with the public conflict which gave rise to their existence. New attitudes and approaches to public planning are required. A framework for principled negotiation is outlined.

INTRODUCTION

At the last fire management symposium I attended, one speaker commented in all seriousness that if it were not for the public their job of fire management would be straighforward. Of course the comment was enormously funny at the time, but I believe it exposed an underlying misconception about the nature of planning and management of public lands.

In this paper I put forward a case that "the public" and "conflict" are a fundamental part of any management planning process. I believe that tools and skills for resolving conflicts and negotiating issues are as important to fire management and planning as maps, computers and fire sticks.

Why Allow Public Participation in Planning?

The short answer to this question is: because we have to by law. So why is there a law? There is no short answer.

I would like to briefly examine the historical social process which brings into existence public Resource Management Agencies with an obligation to involve and consult people. In the last few decades there have been three recognisable stages in the evolution of the conservation issues (Downs 1972).

Recognition

In the 1950s the first environmental alarm bells began to sound. Rachel Carson's book "Silent Spring" drew attention to environmental degradation from pollution and pesticides (Carson 1952). Over the following years more and more issues were recognised and exposed and there was a growing public awareness that all was not well; the welfare of the natural environment was at risk.

Reaction

In the 1960s and 1970s there was a stage reaction. Public groups targeted key industries and issues and directly protested and obstructed development. Governments and development corporations were caught largely unprepared. There was considerable general public interest in environmental issues, a growing public concern that something should be done. Conservation became a political issue.

Institutionalisation

In response to growing concerns over conservation issues governments established environmental agencies such as Environmental Protection Authorities, Soil Conservation Commissions, Fisheries and Wildlife Agencies and Departments of Environment and Conservation to attend to the problems. Our society now pays attention to environmental problems and invests resources to solve them.

It follows that any protest from people or groups concerned about degradation of environmental quality seems less legitimate. After all, there are expert agencies dealing with the problems. Eventually public groups are even invited to be involved on advisory committees and to review plans. I am sure most of us recognise these phases.

It is worth taking a look at the implications of these changes from both the point of view of the conservation movement and from the government agencies.

Perspective I : *Institutionalisation from the Conservative Side*

In the last decade and a half Australia has seen exponential growth in expenditure on official and corporate conservation agencies. On the other hand growth in expenditure and in human resources in the organised conservation movement has been at best moderate.

There has been a phenomenal increase in the number and complexity of issues, and in the number of plans, legal documents and institutional processes to be attended to. By whom? By "the public," and thus representatives of the voluntary conservation movements. In spite of these difficulties the conservation movement has remained responsive, effective and analytical on most major issues. Clearly, however, under these circumstances the movement is forced to react to some issues without adequate analysis or investigation.

To overcome these problems it may be desirable that we in Australia take the Canadian example and provide more substantial funding for public and conservation groups. This may in the long run actually decrease conflict rather than increase it as decisions will be made in a more conciliatory and equitable climate.

It is often claimed that the only time agencies hear from "the public" and conservation groups is at the end of the planning process when they are being critical and unappreciative. The above description hopefully clarifies why this might happen. I also suggest that we have to look more closely at how the agencies approach the planning and public involvement process.

Perspective II : *Institutionalisation from the Agencies' Side*

Environmental problems can be institutionalised, but they don't go away. Public agencies now have the job of managing the conflict as well as the resources, all in a difficult climate.

Agencies have traditionally focused on the biophysical system. After years of investigation into the dynamics of biophysical systems, and just when they begin to understand how these systems may be managed, they are confronted with resounding social and economic issues.

Agencies have seldom investigated what people (including land users, interest groups and their own staff) think, believe, hope and expect about the management of the land. What do people want from their parks and reserves? What responsibilities do we have to future generations? Who best represents the various issues and interests?One could argue, however, that it is the beliefs, perceptions and underlying hopes and fears of people which are the management problem. After all, if no-one in society cared about the bush there would be no need for a management agency.

To answer my original question: Government agencies are required by law to allow public participation because the underpinning political reason for their existence is to resolve conflicts of interests in the use of public resources. Fire management in natural areas is no different.

Conflict Resolution and Negotiation

If agencies are to facilitate public participation in decision making then it is important for them to develop an underlying philosophy about the nature of public planning.

Many public debates over conservation issues end up being time consuming, frustrating and conflict-centred. There is often considerable animosity between various interest groups and the management agency. Lines of communication are poor or non-existent and various factions and the agency bargain from strongly-held positions. This is not a climate in which creative solutions can be designed to resolve the substantive issues involved in the conflict. It is certainly not a climate in which decisions are made efficiently.

For some time I have been interested in decision-making procedures in small groups, and have been looking for procedures and tools to resolve large multi-group conflicts such as those which develop around conservation issues. Fisher and Ury (1986) outline a framework aimed at making negotiation between groups more effective and efficient. They suggest that any method of negotiation should produce: "a wise agreement if agreement is possible. It should be efficient. And it should improve or at least not damage the relationship between the parties. (A wise agreement can be defined as one which meets the legitimate interests of each side to the extent possible, which resolves conflicting interests fairly, which is durable, and which takes community interests into account.)" (p 4).

It is my belief that many of the ongoing conflicts, including those relating to the use and management of fire on natural lands, have resulted from management agencies and interest groups arguing over "positions". As more attention is paid to positions, less attention is paid to the underlying concerns of parties. As a result, many plans and agreements simply represent a mechanical splitting of the difference between final positions rather than solutions carefully crafted to meet the legitimate interests and concerns of the parties.

These ad hoc, splitting-the-difference solutions will most likely produce ecologically unsound management. Since undesirable management decisions arise out of inefficient and inappropriate decision making processes it is worth examing those processes more closely.

Arguing Over Positions is Inefficient

Bargaining over positions creates incentives to stall settlement. To improve the chance that a settlement goes your way you choose an extreme position, hang on stubbornly to it, deceive the other side as to your true views, and you make small concessions (only when necessary) to keep the negotiation going. The more extreme the positions and the smaller the concessions the more time and effort it takes to find out if agreement is at all possible. Clearly such a frustrating process will lead to a sense of mutual disrespect, to poor relations and thus to greater difficulty in reaching lasting mutually beneficial decisions. If an agreement is reached by a series of reluctant concessions and compromises "the losers" (possibly even both sides) may be on the look out for any opportunity to renegotiate. There will be a lack of commitment to the decisions and thus difficulty in implementation. Anyone who has been involved in planning or management will recognise some of these symptoms.

Standard approaches and attitudes to negotiation are not providing a satisfactory means for resolving complex natural resource management problems involving many interest groups. If we are to move towards more efficient and effective ways of planning societies' use of resources we have to establish a better general understanding of how decisions are made.

Negotiation takes place on two levels; firstly on the level of substance relating to basic issues and concerns, and secondly at the level of procedure where the processes for resolving issues and concerns are dealt with. In many situations negotiation procedure is implicit rather than explicit. For effective negotiation both levels must be attended to. The underlying issues and concerns must be clearly established, and fair procedures for resolving those issues developed. If a procedure is perceived to be unfair a lasting solution is impossible.

Principled Negotiation

Fisher and Ury (1986) outline four fundamental elements of the "principled negotiation" procedure. These are not intended as a formula for public participation, but rather provide a way of thinking about our approach to decision making and conflict resolution.

Separate the people from the problem

Negotiation takes place between human beings with different beliefs, perceptions and aspirations. We all know how hard it is to deal with problems without misunderstanding each other. My experience in working for both government agencies and in the conservation movement is that there is often mutual mistrust and stereotyping. Stereotyping conservationists, foresters, bureaucrats and politicians tends to provide a convenient distraction from the issues. Even worse, however, the stereotype characteristics become mixed up with the issues. Consider the implications of these stereotypes underpinning the planning process for a National Park Fire Management Plan.

(a) Conservationists oppose burning the forest. They have nothing better to do with their time than to disrupt our work.

(b) All forest officers are insensitive to the bush. They are primarily concerned with making sure logging companies are happy.

(c) All farmers are pyromaniacs and want to see the bush burnt

All of these beliefs and misconceptions stand in the way of clear thinking about the actual problems. Before working on substantive issues it is important to disentangle the "people issues". Figuratively speaking the participants should see themselves as working side by side attacking the problem and not each other. It would help enormously if those participating in the negotiation made an effort to put themselves in the shoes of the other side and tried to appreciate their perception of the problems.

Focus on Interests, Not Positions.

There are serious problems with focusing on people's stated position when the object of negotiation is to satisfy their underlying interest. The basic problem in a negotiation lies not in conflicting positions but between each side's needs, desires, concerns and fears. Thus, a position is something you decide on but your interests are what cause you to decide.

A bargaining position often obscures what a person really wants. Compromising between positions is therefore unlikely to lead to a solution which takes care of the interests which led to those positions

Consider the following example:

<u>A National Park Neighbour:</u>:
<u>Position:</u> "The park" should be prescribe burned.
<u>Underlying Interests:</u> Concern for the safety of family and family home.
<u>Belief</u>: Broadscale prescribed burning offers the only sure protection against a wildfire burning their house down.

Clearly, arguing over the ecological costs and benefits of fire will not solve this person's problems.

Generate options before deciding what to do.

Many planning processes involve generating options, deciding on the best solutions and presenting a *fait accompli* management plan for public comment.

Unfortunately even the wisest planner would not be able to account for all of the possible interests. More importantly, however, the generation of alternative solutions to problems is a fundamental part of conflict resolution and decision making. It is a process which all parties must be involved in if they are to feel committed to the final decision.

Time should be set aside to invent options for mutual gain before trying to reach agreement. The options should try to dovetail differing interests. People generally believe that differences between parties create problems, yet differences can also lead to the solution.

Agreement may only emerge as the participants begin to understand other parties' needs and when creative options are generated to accommodate genuine interests. Consider the relationship between wildflower pickers who may want an area regularly burned, and the need for rotational burning for protection in some places.

Insist on Objective Criteria.

However well one understands people's interests and however many ingenious options are invented, one may still be confronted with conflicting interests. The bottom line on any conflicting issues must be the criteria used to make the decision.

While parties may not be able to agree on any particular option, they may be able to establish suitable criteria for resolving the issue. Such criteria should represent fair standards which are independent of any parties' will and which apply to all sides. Standards may be derived from precedent, independent scientific judgement, costs, or even what a court would decide.

Agreement on what criteria should be used to make a decision is a fundamental part of the conflict resolution process. If parties mutually agree on what criteria can be used to resolve an issue, an acceptable solution can be generated independent of bargaining position. In the case of a reserve neighbour concerned about the safety of their family and home, they may be happy to use "independent scientific judgement" about risks and hazards to people and buildings in wildfires, as a basis for planning future management.

CONCLUSION

Growing public awareness of conservation issues and the emergence of an organised conservation movement have lead to the establishment of government conservation agencies. Most of these agencies define their purposes almost entirely in biophysical terms, but more recently they have been required by law to facilitate public involvement in management and policy decisions.

The exponential growth in expenditure on Corporate and Public Conservation Agencies has resulted in a proliferation of planning procedures and documents bringing considerable pressure to bear on public voluntary conservation groups with only limited resources. Land management planning exercises often become David and Goliath contests of will power, while many of the substantive issues and concerns are neglected or glossed over.

Conflict is a feature of natural resource management. Decision making and planning is slow, uncertain and often circular as decisions are made, remade and renegotiated. New models and attitudes are needed to negotiate solutions which deal more openly with the underlying issues and concerns of both agencies and interest groups. Methods of "principled negotiation" should be incorporated into the overall approach to public participation. Without these changes it will not be possible to make durable and meaningful decisions about the future management of public lands.

The first steps towards more effective public participation must embrace general education about the nature and purpose of public planning, and also about the nature and purpose of effective conflict resolution and negotiation. These must be followed up by concerted efforts to develop and use negotiation and communication skills in day to day planning and decision making.

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PUBLIC ATTITUDES TO FIRE

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SUMMARY

For most people many of the effects of fire are seen as detrimental to the environment. This attitude is inconsistent with the fact that fire is itself an ancient part of that environment. Very few people ever consider the effects of other factors of the environment on fire.

The origins of this modern imbalance between attitudes and ecology may be related to the concepts of "property" and "damage" which were probably foreign to the pre-existing hunter-gatherer societies.

Changing public attitudes to ecologically sound fire management requires the separation of the legitimate from the unwarranted concerns and this is helped by careful choice of words that are always used in the same way by all fire managers.

INTRODUCTION

Managers of public land should be responsive to public attitudes about their management and explain apparent anomolies. Fire managers of such lands have a particularly difficult task where public attitudes to fire and planned burning are at odds with ecologically sound fire management.

This paper discusses some questions about fire, planned burning and the origins of fire attitudes, and suggests ways of making those attitudes more consistent with the ecology of our fire-adapted vegetation types.

What are the Effects of Fire on Natural Ecosystems?

The usual responses to this question include such things as atmospheric pollution, soil erosion, nutrient losses, eutrophication of water, destruction of soil organic matter and microorganisms, damage to plants, reduction of habitat, and death of wildlife. The words "pollution", "erosion", "destruction", "damage", "reduction" and "death" appear to judge fire's effects as negative from a human point of view. However, fire and recognisably modern vegetation types have existed for at least five million years (Kemp 1981) and fossil pollen and charcoal evidence suggest that fire, vegetation, climate and people were in equilibrium for more than three thousand years before Europeans came to Australia (eg see Figure 2 in Macphail 1980). This equilibrium suggests that there should be many positive fire effects to balance the negative ones listed above. It also suggests that the question itself is biased if the object is to understand fire ecology. A better question might be:

What are the Interactions of Fire in Natural Ecosystems?

Table 1 attempts to list the important known interactions. They are arranged in "positive" and "negative" columns to indicate how they are commonly judged. However, from an ecosystem viewpoint all are neutral. Note that for every "negative" a "positive" can be found and that for nearly every effect of fire there is a reciprocal effect on fire.

Table 1
The interactions of fire in natural ecosystems

Ecosystem Factor	Effects OF Fire		Effects ON Fire	
	NEGATIVE	POSITIVE	NEGATIVE	POSITIVE
Atmosphere	Pollution	Recharge of atmospheric nutrients	Rain, wet air	Lightning, dry air, wind, temperature
Earth	Erosion	Rejuvenation	Down slopes, wet soils	Up slopes, dry soils
Nutrients	Loss	Increased availability	Minerals decrease flammability	Growth of fuel
Plants	Damage	Regeneration waste disposal	Young plants = fire breaks	Old plants = fuel
Micro-organisms	Death (especially fungi)	Regeneration (especially bacteria)	Good decomposition	Poor decomposition
Water	Eutrophication	Increased runoff	Extinguishes (present water)	Better growth of fuel (past water)
Animals	Loss of habitat	Green pick	Eat fuel	(?)
Hunters and gatherers	Injury, (death)	Easier hunting Easier gathering	Suppression (?)	Ignition
Fire	Loss of fuel (different times)	Increased intensity (same time)	Loss of Fuel (different times)	Increased intensity (same time)
Time	-	-	Less fuel (less time)	More fuel (more time)

Where do Fire Attitudes Come From?

A society's attitudes to fire are probably determined by the balance between fire's values on the one hand and its dangers on the other. This balance changed as hunting and gathering was replaced by animal husbandry, agriculture and fixed dwellings. Table 2 examines some of the values and dangers of fire in relation to three societies. This information suggests that fire was a vital tool for hunters and gatherers and apart from children burning their fingers, posed no threat to people or property because there was no property other than that which could be carried.

On the other hand the present city dwellers, who make up 80 per cent or more of our present population, have very little use for fire. However, their lives, immediate environment and nearly all their property are, every so often, severely threatened by it. "FIRE!" is one of the most alarming words in the language. It is used to wake people out of deep sleep and get them out of their flammable houses before their flammable clothes are ignited. Fire for most people is equated with danger, the devil and hell.

Between the two extremes are today's land managers. They are aware of fire's values as a tool but they are also aware of fire's dangers; not just to single dwellings but to whole settlements. It is this concern for life and property in general (and not just for themselves) that has led most managers of flammable native vegetation to use planned fuel reduction burning to prevent the undesirable effects of bushfires.

Table 2
The Values and Dangers of Fire

Value or Danger	Hunters and Gatherers	Modern land Managers	Modern city Dwellers
Warmth	Vital	Some	(mostly oil, gas and electricity)
Cooking	Vital	Some	(mostly oil, gas and electricity)
Rubbish disposal	?	Some	Some
Hunting	Vital	Some	Nil
Access	Important	Some	Nil
Regeneration, green pick	Vital	Vital	Nil
Fuel reduction	?	Vital	Nil
Injury	Some	Some	Some
Life threat	Slight	Serious *	Serious **
Property damage	Nil	Serious *	Serious **

* *Settlement fire* ** *House fire*

Does Fuel-reduction Burning Mitigate Bushfires?

The bottom half of Figure 1 (from Australian Forestry Council 1987) shows that within Western Australian forests the systematic fuel-reduction burning policy implemented after the Dwellingup fires does reduce bushfires. Not only are the areas burnt each year reduced but the system stood firm against cyclone "Alby" and all its fires - a much more serious combination than that which burnt Dwellingup.

The top of Figure 1 shows that Tasmania, with a similar sized forest resource and a similar fire pattern up to 1961 was unable to prevent the 1967 disaster which killed 62 people and destroyed 1 400 houses. It was only after three more bad years (1973, 1982 and 1983) that the need for systematic fuel-reduction burning of flammable vegetation types was accepted and it will be several years before it is fully operational.

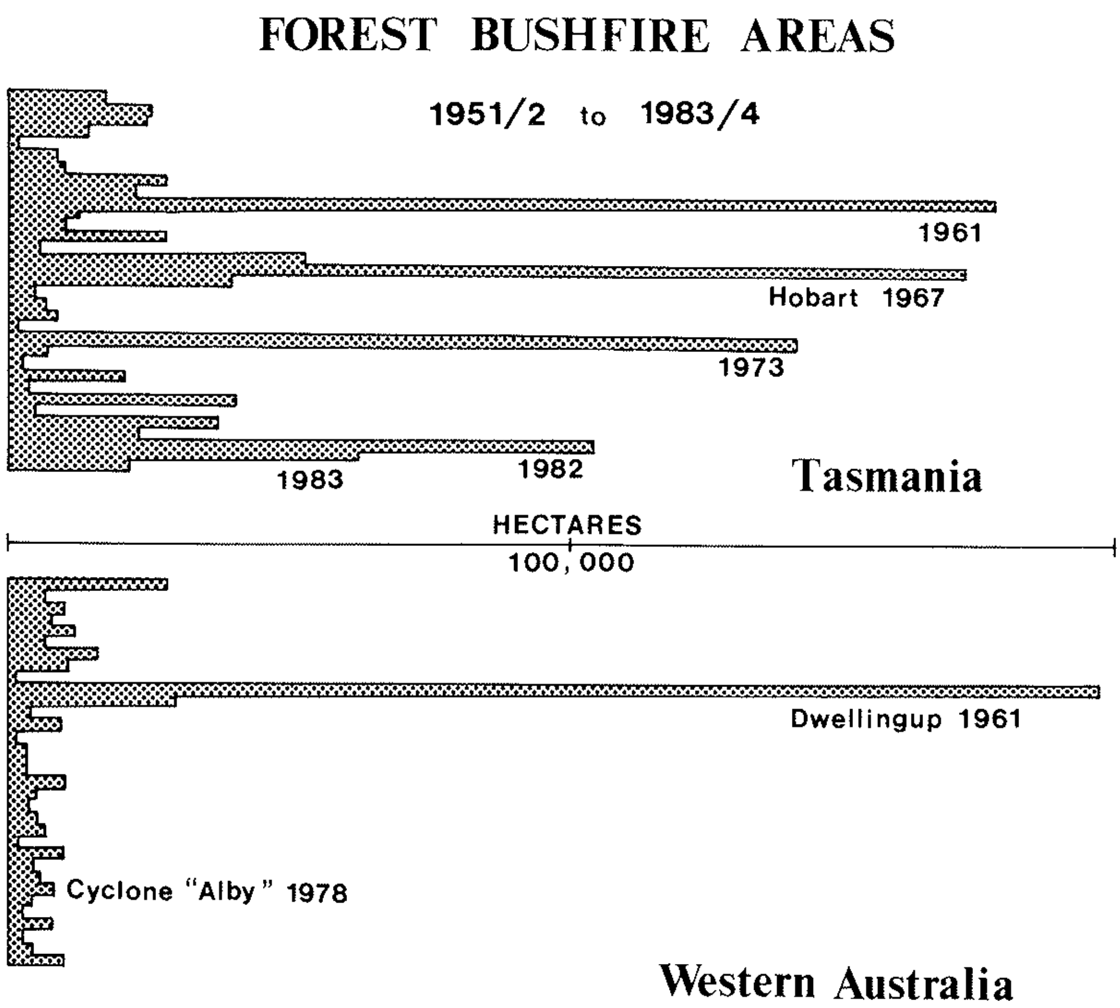

FIGURE 1

Why is Fuel-reduction Burning Opposed?

If the city-dwelling majority does indeed equate fire with danger then it may very well see those who use fire as dangerous. Those who have been to university or seen botanical text books are likely to have had any existing aversion to fire reinforced. This is because most of these books come from the USA and in nearly all of them the fire story and pictures come from the US Forest Service. Fire is presented as mostly ignited by people, as doing enormous damage and disturbing the supposedly natural "succession" to theoretical self-perpetuating "climax" vegetation types. (This standard version even appears in those texts that discuss lightning fires; that show that insects and disease account for far more damage than fire; and that have to invoke the self-contradictory term "fire climax" to reconcile observation and theory (eg Dasmann 1968).)

Which of the Common Concerns are Unwarranted?

Some of the concern about "unnatural" burning arises from the tradition of blaming the fire lighter for the fire size and damage. It fails to appreciate that in natural fuel accumulations the natural fire weather largely determines fire size, intensity, damage and difficulty of control. Although ignition timing and patterns also affect these factors, the ignition mechanism (matches, spark or lightning) does not.

Other concerns involve fire intensity and fire frequency. These may stem from the view that fire is something new in the environment. Once it is realised that the flammable vegetation types have probably fuelled and survived at least 100 000 fires since they evolved it will also be appreciated that the natural range in either fire frequency or intensity is unlikely to be extended by planned burning. However, there should be concern about any new factors in the environment that may interact with fire. These include introduced animals (eg rabbits, sheep), plants (eg gorse, annual grasses), fungi (eg *Phytophthora*), insects, chemicals and machines.

What Can Be Done about Public Attitudes?

(a) We should continue to use the word "fire" in its traditional role as an alarm, for bushfires and for general discussion of combustion, but avoid using it in connection with planned burning.

(b) We should use the term "burn" or "burning" whenever the ignition is planned and legal (eg "burning permit period") and the term "arson" or "incendiarism" for illegal use of fire.

(c) We should include fire education in high school curricula and make clear the distinction between bushfires and planned burning. We should show everybody how to visually estimate fuel quantities, explain just how helpless we are when a lot of fuel is alight on a bad day and how effective fuel reduction is in reducing bushfire damage.

(d) We should promote the balanced presentation of fire in botanical and land management courses at university, along the lines shown in the "background" section of "Australian Bushfire Research" (Australian Forestry Council 1987), at least until some truly Australian fire ecology text books are written.

(e) We should answer "Letters to the Editor" about fire with copies of "Australian Bushfire Research" and send a copy to the editor as well.

(f) We should explain that, unlike a house, fire-adapted vegetation cannot be "destroyed" by fire alone. It may be damaged but, unless prevented by some new factor, it will recover as it has always done before.

(g) We should quantify damage in dollars and add it to the fire-fighting bill and to the income foregone because of the resources lost. The full costs of bushfires should be widely published and carefully compared with that of fuel-reduction burning. We should also quantify and publish the dollars saved by both fire-fighting and fuel-reduction burning.

(h) Recognising that there is currently more acceptance of fire-fighting than of planned burning, we should consider bringing some bushfires out to safe edges in the evening before the next bad fire day. This may require changing suppression objectives from minimum area burnt to minimum time alight. It may also require new ways of salvaging the few trees likely to be felled by such fires.

(i) We should recognise that, unlike most of our fuel-reduction burning, the percentage of area burnt by bushfires, when the soil was moist and the fire weather easy, was very small. We should check that our lighting patterns, burn sizes and seasons have pre-european equivalents.

(j) We should identify those who are interested in or critical of planned burns and ask them to help monitor both bushfire and planned burning effects.

(k) We should listen carefully to informed critics and share burning and bushfire problems with them.

(l) We should letterbox those who choose to live in "sylvan settings" and offer advice on how to reduce their fire risks.

(m) We should explain fire ecology to visitors to National Parks along the lines shown in Tables 1 and 2 above and in "Australian Bushfire Research".

(n) We should explain that the plants and animals present today have survived more than 40 000 years of human ignition and that in some places where this has ceased, some animals have become extinct and some forests have died. To arrest these problems we need to integrate those ancient burning practices with the protection of modern values and property.

(o) We should run courses in fire for journalists and explain how, with their help, the Hobart and Ash Wednesday disasters need never happen again. We should ask them to report the dedication and skill of those who keep fuels low just as much as they now praise the occasional heroics required wherever such fuels are allowed to accumulate. Both stories can have the human touch. We should ask them to help remove the current impression that heroes fight and only villains light. Are not the true heroes those who do the right thing when all about them say "nay"?

CONCLUSION

As managers of public land in Australia we need to find out which people are concerned about fire and what those concerns are. We need to understand their main sources of information about fire and to recognise gaps and misinformation. From this base we can diminish unwarranted concerns about planned burning and respond quickly to valid ones.

We need to be much more rigorous in fire research and in the editing and refereeing of fire research papers. We should discredit the narrow philosophy that fire is just "a disturbance factor", and instead, promote its role as an ancient and integral part of most Australian ecosystems. We should try to supply balanced information to all those interested in fire and planned burning.

We should generate debate about "blame" or responsibility for bushfire's effects and make sure that those who own the fuel receive at least as much attention as those who irresponsibly or maliciously ignite it.

We have ahead of us a major task to make public attitudes to fire more consistent with the facts of fire ecology. The prize is public support for those actions that will not only prevent future settlement holocausts but also take care of our fire-adapted plants and animals.

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DISCUSSION

by Neil Burrows, Lachlan McCaw and Gordon Friend

INTRODUCTION

Workshop syndicates were set the task of establishing a procedure for fire management planning on nature conservation lands. To add a sense of realism to the exercise, each syndicate was provided with a case study involving a National Park or Forest Reserve in Western Australia. Case studies were chosen to reflect the range of circumstances facing conservation land managers in Western Australia. A summary of the important characteristics of each case study is shown in Table 1.

At one extreme is the Hamersley Range National Park of some 617 606 hectares set in the heart of the remote, arid Pilbara region in the state's north-west. Relatively little is known of the ecology and biogeography of the Park and few resources are available for management. Extensive areas of the Park have been burnt by wildfires in recent years. The Park is rapidly becoming a popular destination for organised tourist and expedition groups.

The Walpole-Nornalup National Park represents the other end of the spectrum. This Park of 17 986 hectares is situated on the southern coast of Western Australia in a region experiencing a Mediterranean-type climate. The ecological and biogeographical data bases available for the Park are relatively comprehensive and sufficient resources are available for a range of management activities to be undertaken. The use of prescribed burning to control fuel accumulation within the Park is locally controversial. In recent years arson has been responsible for a number of costly and potentially dangerous fires within the Park.

Syndicates were provided with specially prepared booklets that summarised the available information about a number of factors influencing fire management. These included:

- details of reserve location, size and tenure
- climate
- topography, soil and landform
- legislation affecting management
- current management objectives
- historical and current patterns of useage
- fire history

Table 1
A brief comparison of the major features of the study areas used for the syndicate planning exercise

	Walpole-Nornalup National Park	Dryandra State Forest	Fitzgerald River National Park	Hamersley Range National Park
Location (latitude/ longitude)	35^0S $117^0$30'E	33^0S 117^0E	34^0S $119^0$30'E	23^0S $118^0$0E
CALM Administrative Region	Southern Forest	Wheatbelt	South Coast	Pilbara
Area of Reserve	17 986 ha	23 500 ha (comprised of multiple blocks of which the largest is 12 200 ha)	242 804 ha (extensions of 51 000 ha planned to the northern section of the park)	617 606 ha
Rainfall amount and seasonality	1400 mm Winter	500 mm Winter	500 mm Winter	300 mm Summer
Phytogeographic context				
Province	South west	South west	South west	Eremean
District	Darling	Avon	Eyre	Fortescue
Sub-district	Warren	Dale	-	-
Dominant physiognomic vegetation type	Tall forest	Woodland	Mallee and scrub heath	Hummock grassland and mulga low woodland
Adequacy of ecological data base relevant to reserve management ranked from best (1) to least (4)	1	2	3	4
Availability of resources to implement management - ranked from best (1) to least (4)	1	2	3	4
Recreational usage - ranked from highest (1) to lowest (4)	1	2	3	4
Notable features	Park contains best stands of mature Red tingle (*Eucalyptus jacksoni*) tall open forest	Remnant of woodland in an agricultural landscape. Refuge for rare and restricted fauna	Rich, endemic flora. Refuge for rare and restricted fauna. Registered as International Biosphere Reserve with UNESCO	Spectacular gorges and associated vegetation in semi arid environment. Significant aboriginal sites.

- important constraints to management
- resources currently available for management
- known ecology and biogeography of the reserve.

Additional information was made available in the form of posters, maps and slide presentations. Each syndicate was also able to call upon the experience of two mentors with good local knowledge and experience of the case study in question.

Each of the case studies was addressed by two syndicates containing 7-8 members from a variety of backgrounds. Following a day and a half of deliberation, each syndicate was required to give a short presentation describing the procedure that they had adopted and the key features of their plan.

Here we have attempted to summarise the syndicate presentations. Given the abstract nature of planning, this proved to be difficult. The method of presentation varied as did nomenclature and expression syntax. From the syndicate presentations, we identified the major tasks (headings) of the planning process and the components (sub-headings) of each task. These were summarised in table form for the purpose of comparing the various approaches adopted by each syndicate.

RESULTS

The major tasks in the fire management planning process to emerge from the exercise are presented in Table 2. The sequence in which each syndicate undertook the individual tasks is also shown in Table 2. Components of each task are summarised in Table 3. We letter-coded each task (Table 2) in order to show the task-component relationship developed by each syndicate (Table 3).

The planning approach adopted by syndicates was not related to the nature or characteristics of the case studies, but was dominated by the preferences and past experiences of individuals making up the syndicates. Most syndicates started the planning process by examining the reasons for the gazettal of the park (overall goals), legal responsibilities and social and ecological issues in relation to the park. The major departure from this was Syndicate 4, who commenced by specifying planning principles (see Appendix 2).

Data assembly was an important early process. Some syndicates set fire management objectives only after assembling all known information, whereas others set objectives based on legal responsibilities alone. Most syndicates considered that key management issues could be defined on the basis of local knowledge and experience and a brief overview of data rather than through an exhaustive review of the data base. All syndicates agreed that lack of data was no excuse for failure to prepare a management plan. One syndicate made the point that lack of knowledge and information was an important reason for formulating a management plan.

Table 2

Major tasks in the fire management planning process as identified by syndicates. Numbers indicate the sequence in which each syndicate undertook individual tasks

TASK	SYNDICATE 1	2	3	4	5	6	7	8
(A) Review legislative responsibilities and requirements		1					1	
(B) Establish overall goals for management of the reserve				2	1	2	2	1
(C) Identify critical issues (ecological and social) in reserve management on the basis of local knowledge and a brief overview of available resource information		4	1			1		
(D) Set specific, ranked objectives for management of fire in the reserve	1	5	2	4	3	4	3	2
(E) Undertake an objective analysis of the threat posed by wildfire to different resource categories		2						
(F) Specify the underlying principles employed in the planning process				1				
(G) Assemble a data base containing all currently available resource information relevant to fire management in the reserve	2	3	3	3	2	5	4	
(H) Divide reserve into zones within which consistent management strategies can apply						3		3
(I) Formulate strategies to meet objectives, (taking account of specific requirements created by zoning, if employed)	3	6	4	5	4	6	6	4
(J) Identify key constraints affecting fire management objectives							5	5
(K) Establish a monitoring system that can indicate the extent to which management objectives are met	5	7	5	7	5	7	7	7
(L) Initiate further research into areas where management is constrained by inadequate knowledge	4				6	8		
(M) Review fire management objectives and strategies to ensure that they are consistent with each other and with overall goals.				6				6
(N) Prepare works programs and prescriptions to facilitate implementation of the plan						9		8

Table 3
Components of the major tasks in the fire management planning process as identified by syndicates. Letters refer to major tasks as listed in Table 2

COMPONENTS OF MAJOR TASKS	SYNDICATE							
	1	2	3	4	5	6	7	8
Reasons for proclamation of park	D	AD	BD	BD	BD	BD	BG	BD
Statutory requirements of agency	D	AD	BD	BD	BD	BD	BG	BD
Legislation in relation to the built environment		AD		BD			G	
Legislation in relation the rare flora and fauna		AD	BD	BD	BD	BD	BG	BD
Legislation in relation to bushfires		AD		BD	D	BD	BG	
Management history, past land use	DG	D	BCD	BD	D	D	G	
Fire history (planned and unplanned)	DG	D	BCD	GD	D	D	G	
Regional importance of park	D	D	C	BD		CD	BG	BD
Local community aspirations		C	B	BD	CD		BG	BD
Identify issues and stake holders - liason	D			FB	BD	CD	G	D
Location of settlements, towns, recreation sites	G	D		BD	D	D	G	J
Tenure and use of surrounding lands	G			D	D	G	J	
Wildfire threat analysis/values at risk		D	D		CD		I	
Consistency of fire management objectives	D		D		D	D	D	D
Objectives based on sound ecological principals	D	D		D	D	DI	D	D
Objectives must be achievable, accountable		D	D		D			
Fire management plan must be regionally integrated		DC	D		D	D	DI	
Specify planning principles				F		B		
Specify purpose and life of plan				F	C	B		
Specify methods of public involvement				F	CD	B		
Rank objectives and goals		D	DB	B	BD	BD	B	
Liase with public re management objectives	D			BD	BDI	CHD	H	
Collation of ecological and biogeographical information	DG	D	DI	BGD	GD	CHD	G	DHJ
Topography,landform and soil maps	G	DI		GD	GI	DIH	G	DHJI
Fuel and vegetation maps	G	DI		GD	GI	DIH	G	DHJI
Fuel dynamics and fire behaviour models	G	DI	I	GD	GI	DIH	G	DHJI
Rare flora and fauna location maps	GK	DAI	CD	GDK	GI	DIH	G	DHJI
Location of disease	G	AID	CD	GDK	GI	IH	G	DJI
Fire ecology information	K	D	CD	GD	GI	DIH	G	DHJI
Fire sensitive flora and fauna	GK	D	CD	GD	GI	DIH	G	DHJI
Life cycles of selected taxa	G	D	CD	GDK	GI	DIH	G	DHJI
Identify biological indicators		D	CD	GDK	GI	DIH	G	DHJI
Identify gaps in knowledge, initiate research	G	I	I	BGI	GI	DI	GI	I
Identify special landscape features		D		GD	GI	IH	G	DI
Provide access routes, determine visitor useage patterns	G	D		D	GIK	IH	G	DI
Determine recreation trends, demands, impacts	G	D	BCI	DK	GIK	I	G	
Educate public about fire ecology and park attributes		I	I		DI	D	G	
Assess climate and local weather conditions	G	D			G	D	G	DJ
Human resources, machines and money		D	BCI	I	G	DI	GI	JI
Assess suppression capability		D	D			G	DI	GI
Safety measures; park visitors and staff		D			I	DI	GI	JI
Close access to park when fire weather is severe		I			I	I	I	I
Determine management units from ecological boundaries	I	I	I		I	H	I	HI
Zone within management units	I	I		I	I	H		HI
Prepare fire management strategy for each zone	I	I	I		I	HI		HI
Locate firebreaks and low fuel buffers	I	I			I	I	I	I
Implement prescribed burning where necessary	I	I	I		I	I	I	I
Investigate wildfire control options				I	I	I	I	II
Ensure public participation in strategy development				I	I	I	I	II
Monitor changes to park flora and fauna	K	K	I	K	K	K	K	K
Record wildfire details		K	I	K	K	K	K	K
Record all operational details		K	I	K	K	K	K	K
Monitor disease, erosion, feral animals, weeds	K	K	I	K	K	K	K	K
Involve local community in monitoring	K			K		K	K	K
Review and reset objectives and strategies		I	I	IK	D	IK		KI
Develop working prescriptions						N	I	N

Similar concepts were often expressed in different ways and this partially explains the long list of components in Table 3. For example, Syndicate 2 specified wildfire risk analysis as being a major first step, whereas other syndicates considered this to be equivalent to and part of the process of issue identification.

All syndicates considered monitoring to be an essential process to provide feedback on effectiveness of management. However, opinions were divided on how this could be achieved.

All syndicates recognised the importance of public participation and liaison with interest groups throughout the planning process. As with monitoring, opinions varied on how this should be done. Syndicate 6 considered this aspect to be the foundation of a successful management plan. They maintained that stake-holders needed to be identified and involved at the objective setting stage and during the process of developing strategies. Syndicate 6 felt that most conflict concerning fire management was about strategies rather than objectives or goals.

Discussion - Towards A General Planning Framework

A number of common themes for fire management planning emerged during the course of the syndicate planning exercise. This was despite the fact that the four case studies considered by the syndicate groups differed considerably in a number of important respects including reserve tenure and purpose, size, environmental and ecological characteristics, resources available for management and the nature of local community attitudes. The fact that a considerable degree of commonality was evident in the planning procedure adopted indicates that a generalised framework for fire management planning on nature conservation land is achievable and probably desirable. The existence of such a framework could be of considerable assistance to land management agencies throughout Australia.

We propose the following as a general framework for planning fire management in Australia.

General Planning Principles

Planning is an abstract process and it is therefore crucial that concepts and ideas be communicated simply and effectively to avoid confusion. Key words used frequently in planning literature such as goal, policy, objective, aim and strategy are often not defined or consistently applied; this situation may apply between organisations and within different documents produced by the same organisation. Therefore we have adopted the definitions presented by Underwood at this workshop and recommend that they be used in future planning documents.

Briefly, the definitions used are:
goal - a long term desirable situation
objective - a clear statement of a result to be achieved within a stated time frame, and oriented to a goal
strategy - a means by which an objective may be met.

- Where the planning process identifies gaps in knowledge, the plan should include relevant measures to fill gaps, such as the need for experimental management and monitoring.

- Planning should be dynamic to reflect the nature of nature. The life of the current plan and timing of reviews should be specified.

- Decisions can be made on the basis of minimum information but the process of information gathering should follow.

- The less complete the data set, the more important it is to involve the public at an early stage. How this is to be done must be specified in the plan.

- Land use planning is an important adjunct to fire management.

Goals

Management goals for the overall management of the park or reserve must be clearly stated at the outset of the fire management process. These will evolve from the legislation and reasons for the gazettal of the park. Normally, goals will be stated in the context of a park or reserve area management plan, or in the absence of such, within a set of interim guidelines that specify the minimum operations considered necessary to maintain and protect existing reserve values. Ranking of goals to reflect the circumstances of the particular land is generally desirable, as is the inclusion of goals that relate directly to the management of fire.

Acceptance of goals by the public and by the agency staff is a necessary pre-requisite in subsequent stages of the planning process. Education and public participation programs may be required to achieve general acceptance.

Fire Management Objectives

Specific objectives for fire management should be consistent with and orientated towards the stated management goals. Objectives should be expressed in a way that allows them to be used to periodically evaluate the effectiveness of management actions via a well designed monitoring process. Formulation of fire management objectives should be preceded by a review of relevant fire-related social and ecological issues. A framework for enquiry and for eliciting necessary information such as identifying values, biotic resources, location of rare flora and fauna, fire ecology, fire history, etc. (see Tables 2 and 3) should be developed. Specific fire management objectives arise from a knowledge of natural processes, values and biotic resources. Selected public involvement is necessary at this stage. Other factors that will influence the formulation of objectives include various pieces of legislation, departmental policy, and the extent and depth of data and knowledge about fire related issues. As objectives must be achievable, management constraints such as resources, weather conditions, access, etc. will also influence objective setting.

Strategies

An important criterion in selecting management strategies is that they are practical, measurable, can be stated clearly and expressed in terms of action plans or prescriptions. A whole array of management options should be generated initially to meet objectives. This array should be reviewed to ensure internal consistency and practicality of strategies. Again, this review provides an opportunity for widespread public participation. After the review, strategies can be finalised. While the strategies may be stated in fairly general terms, action plans and prescriptions must be clear and direct.

Monitoring

It is vital to monitor the effect of strategies to evaluate the success in achieving objectives. Monitoring also provides a valuable source of information necessary to review and re-set (if necessary) objectives and strategies. Monitoring techniques are discussed by Gill and Nicholls, Hopkins and Heislers (this publication).

CONCLUSION

Over the last ten years or so, numerous management plans have been prepared for lands including National Parks, Nature Reserves and State Forests across Australia. Plans vary considerably in content and detail, depending on the purpose. In many States, such plans are statutory requirements under the legislation of land management organisations. Most land management plans ultimately aim to ensure the optimum management of land values over a period of time resulting in the continued availability of these values. However, planning for management of nature conservation land also serves other functions which include:

(a) the protection of conservation values from land uses which are contradictory to public expectations,

(b) a means of achieving public involvement in the management of lands and for informing Government and the public as to how and why lands will be managed,

(c) a process for identifying land management issues and their resolution,

(d) the provision of guides for day to day operations,

(e) the collation of known information and data and the identifiction of further research needs,

(f) as a basis for national resource allocation and for determining likely future needs.

Fire management on conservation lands continues to be controversial. We hope that this workshop and these proceedings will be a positive contribution to the process of fire management and to the conservation of our biological resources.

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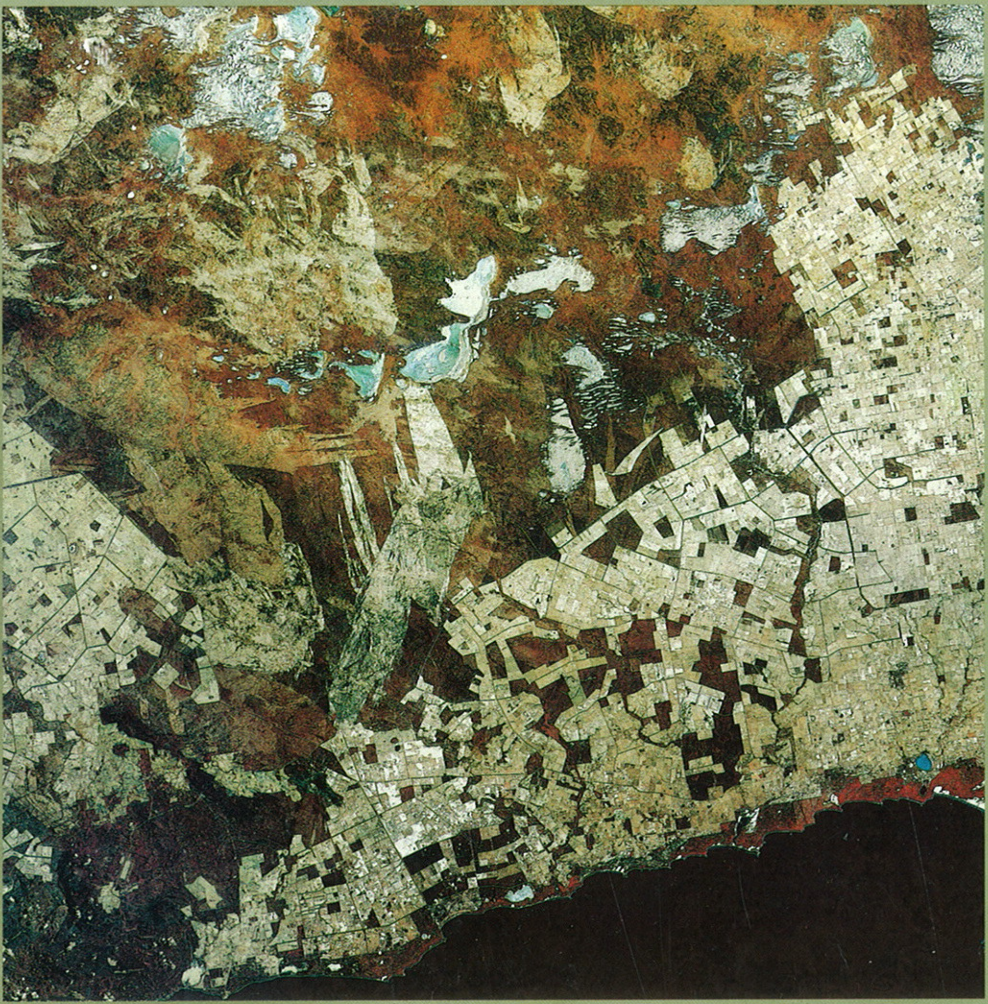

SATELLITE IMAGE OF THE AREA AROUND RAVENSTHORPE, WESTERN AUSTRALIA SHOWING THE EASTERN PORTION OF THE FITZGERALD RIVER NATIONAL PARK (BOTTOM LEFT OF PICTURE) AND UNALIENATED CROWN LAND. A NUMBER OF LARGE FIRES ARE EVIDENT IN THE REMAINING TRACT OF NATIVE VEGETATION

LANDSAT IMAGERY PROVIDED BY REMOTE SENSING, APPLICATION CENTRE OF THE WA DEPARTMENT OF LAND ADMINISTRATION