Fire Management in the Rangelands

A report to the Australian Government Department of Environment and Heritage prepared by the Tropical Savannas and Desert Knowledge Cooperative Research Centres

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Abbreviations and acronyms

ACB	Aerial Control Burning
ACRIS	Australian Collaborative Rangeland Information System
AGO	Australian Greenhouse Office
ANZECC	Australian and New Zealand Environment and Conservation Council
ANRA	Australian Natural Resources Audit
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
BFCNT	Bushfires Council of the Northern Territory
COAG	Council of Australian Governments
CRC LEME	Cooperative Research Centre for Landscape Environments and Mineral Exploration
CSIRO	Commonwealth Scientific Industrial and Research Organisation
DEH	Department of Environment and Heritage
DK CRC	Desert Knowledge Cooperative Research Centre
IBRA	Interim Biogeographic Regionalisation of Australia
MODIS	Moderate-resolution Image Spectroradiometer
NHT	Natural Heritage Trust
NLWRA	National Land and Water Resources Audit
NOAA AVHRR	National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer
NRM	Natural Resource Management
NT DIPE	Northern Territory Department of Infrastructure, Planning and Environment
TPC	Thresholds of Potential Concern
TS–CRC	Tropical Savannas (Management) Cooperative Research Centre
VRD	Victoria River District
WA DLI	West Australian Department of Land Information

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Project brief

This review of fire management in the Australia's rangelands was commissioned by the Australian Department of Environment and Heritage under the Natural Heritage Trust.

The aims of the project were to provide information and resources to:

- assist Australian Government officers assess the adequacy and effectiveness of proposed rangeland fire management programs and projects for NHT2.
- improve the regions' ability to plan for and implement fire management plans/strategies, drawing on a comprehensive overview of past projects and best-practice.
- assist in the implementation of ecologically sustainable fire management in the rangelands.

The main components of the project were to:

- Summarise and consolidate the reasons that fire management in the rangelands is an Australian Government priority.
- Collate and synthesise current information related to the fire-ecology of rangeland ecosystems/vegetation types.
- Recommend fire-frequency thresholds for the major vegetation types in the rangelands (where sufficient literature is available).
- Research and make recommendations into the transferability of fire management research across the rangelands and from south-eastern Australia to the rangelands.
- Develop a checklist for good fire management planning.
- Assess gaps in current fire management knowledge and information based on previous experience and/or the review of past research and projects.
- Identify priority regions in the rangelands where fire management plans are needed or should be improved (i.e. fire management hotspots).
- Develop a list of past projects with proponent details, funding amounts, date, location and a brief summary and categorise (e.g. by vegetation type, season, management objective).

Brief summary

Why fire management is important for natural resource management in the rangelands

The rangelands of Australia have a high biodiversity value: high species diversity, significant numbers of endemic species, areas of ecological and geo-morphological integrity, unique ecosystems and habitat for rare and endangered species. The rangelands are relatively intact with little clearing compared with the areas of intensive agriculture in eastern, southern and south-western Australia. Australia's rangelands are an important refuge for Australia's biodiversity.

Despite the relatively low level of disturbance in the rangelands, the abundance and richness of rangeland biodiversity is declining and there is evidence that inappropriate fire regimes are partly responsible. Fire is an integral part of the ecosystems of Australia's rangelands. Fire management is one of few management tools available to land managers in this zone. Sustainable pasture production is dependent on the maintenance of the resource base (soils and pastures) through sound fire management practices in the short and long term. These fire management practices will have significant impacts on biodiversity conservation. Therefore "understanding how fire affects biodiversity has national significance". (Dyer et al. 2001).

Impacts of various fire management practices on the environment—at regional and local/property scales

Fire management practices are a major factor affecting the ecological function and biodiversity of all ecosystems in the rangelands. For any region or sub-region, desirable fire management practices will vary with the desired management outcomes, and the climate, terrain and flora and fauna assemblages present, as well as the scale of the ecosystem mosaic. Some elements of rangeland ecosystems are resilient to variations in fire regime, others are sensitive to fire intensity and/or sensitive to fire interval. Therefore, no single fire regime applied at landscape scales can meet the needs of any one

major land management objective (e.g. biodiversity conservation), let alone multiple land management objectives.

Key sources of information for natural resource management planners

This report contains a checklist for fire management plans in the rangelands (Section 2), with links to a range of information:

- definitions of terms and concepts
- descriptions of the major vegetation types within the rangelands followed by a list of key references
- communication principles and planning priorities
- a list of sources of information, i.e. fire species attributes, and fire and land use mapping resources
- Links to other resources.

Executive Summary

1. Management of rangelands is a national priority

Rangelands can be defined as lands where livestock are grazed extensively on native vegetation, and where the rainfall is too low or erratic for agricultural cropping. They cover about 70% of Australia, in both temperate and tropical regions. The main vegetation types in the rangelands are native grasslands, shrublands, woodlands and open forests.

Rangelands are important culturally, socially and historically for both Indigenous and non-Indigenous Australians. The economic interests in the rangelands include mining, tourism, meat and wool production. The rangelands have high biodiversity value, however there is mounting evidence of declines in biodiversity values in the rangelands, and inappropriate fire regimes are partly responsible.

Fire is an integral part of most of the rangelands, and is more extensive than in the more mesic and more densely populated areas beyond the rangelands in southern, eastern and south-western Australia. Fire is a major tool for land management in the rangelands, and can be used to meet a range of land management objectives such as enhancement of biodiversity or pastoral production, abatement of greenhouse gas emissions, protection of sensitive habitats or culturally significant sites, and management of woody thickening.

The Australian Government is committed to improving land management practices and protecting areas of high conservation significance in the rangelands. This commitment includes giving “priority funding under the Natural Heritage Trust (NHT) to projects in the rangelands which identify and protect areas of high conservation significance, improve fire management practices, and implement total grazing practices which conserve biodiversity and lead to more sustainable management of rangeland ecosystems”. In short, understanding how fire affects biodiversity has national significance.

One of the key findings of the State of the Environment Report (2001) was that although fire mapping has improved, the effect of various fire regimes on the conservation of biodiversity remains uncertain, indicating the need for more investigations and improved management. There is increasing evidence that current fire regimes in the rangelands are having adverse impacts on both biodiversity and production values. Thus, there is a need to change the current situation, by implementing better fire management practices; the NHT has a potential major role in facilitating such changes.

2. Fire management planning checklist

Fire management planning is one aspect of wider Natural Resource Management planning. The efficacy of regional NRM plans will depend on the processes of development and implementation of the plan, as well as the contents of the plan. In particular these processes include the formulation of the plan, implementation of the plan, monitoring of target outcomes and adaptation of the plan. A checklist details the key planning processes and elements to be included in the fire management component of the regional NRM plans, and includes:

1. Planning process

- Consultation
- Reference to existing information and plans
- Ownership of plan

2. Components of the Fire Management Plan

(a) Information

- Vegetation, species and ecosystem information
- Fire history and fire regimes
- Mapping
- Specialist advice
- Information management
- Indigenous information

(b) Objectives and Targets

- Long and short term objectives,
- Fire management action targets
- Associated resource condition targets
- Developed through consultation with stakeholders

(c) Options/Alternatives

- Limitations
- Consistency with other objectives
- Alternatives

(d) Priority Setting

- Cost-benefit evaluations
- Consideration of biodiversity conservation targets
- Sites of significance

(e) Implementation

- Appropriate mapping
- Costings
- Capacity

(f) Monitoring and review

- Monitoring of fire regimes
- Monitoring of ecological values
- Adaptive management

3. Fire ecology of rangeland ecosystems

Principles of fire ecology

Fires are recurrent disturbances in virtually all landscapes. The ecological effects of fire are most profoundly shaped by fire regimes and to a lesser extent by individual fire events. Fire regimes operate through the collective effects of fire frequency, intensity, season and type. The intervals between fires are an important component of fire regimes. The components of fire regimes vary in complex ways in space and time.

At the continental scale, we can recognize three major climate / fire regions:

The wet–dry tropical savanna region of northern Australia, the semi-arid and arid interior, and the southern temperate zone. The majority of Australia's rangelands are located within the first two of these climate/fire regions.

Climate, soils, and disturbances (including fire) affect biodiversity and the patterns of biodiversity across the landscape. With respect to fire, biodiversity is affected by variation in fire season, fire intensity, fire type and, importantly, the intervals between fires. Both the quantity and quality of animal habitat may be affected by fire regimes. The degree of sensitivity to fire regime components is determined by the characteristic biology or 'life history traits', or attributes, of plant and animal species.

The sensitivity of species to fire may be in terms of responses to fire intervals ('fire-interval sensitive' species) and/or to fire intensity ('fire-intensity sensitive' species). Individual species that occur at a given point in the landscape will be able to cope with some portion of the possible spectrum of fire regimes. Fire regimes beyond the capacity of a particular species to cope may result in the decline and eventual loss of that species from that point in the landscape. Knowledge of these limits and the way they vary among the biota characteristic of any particular ecological community is of obvious management significance.

People have used fire as a land management tool for many thousands of years. The effects of management activities—be they prescribed fire or deliberate fire exclusion—need to be understood in the context of local and regional fire regimes. Different fire regimes can have different impacts on fuels, fodder or biodiversity by changing the composition of plant species and by altering habitats. Different land management goals may require the implementation of different fire regimes.

Management can affect fire regimes through alterations to rates of ignition and spread of fires via prevention and suppression activities. The sensitivity of fire regimes at landscape scales to variation in management is a major question for all landscapes in Australia, but is incompletely, and largely poorly, understood. However, progress has been made in some parts of Australia in using attributes of species to derive biodiversity-oriented guidelines for fire management.

Fire ecology of broad vegetation types

This report summarises the fire ecology of eight major broad vegetation types, and the primary sources of information about fire ecology for these types. Within these major vegetation types there is discussion of some of the minor, fire-sensitive communities and assemblages that occur within these vegetation types and some discussion of trans-boundary issues. The eight major vegetation types discussed are:

- Tropical eucalypt forests and woodlands (savannas)
- Melaleuca woodlands
- Tussock grasslands
- Hummock grasslands
- Temperate eucalypt and open woodlands
- Acacia forests, woodlands, open woodlands and shrublands
- Chenopod shrubs, samphire, forblands
- Mallee eucalypt shrublands

The general distribution of these vegetation types is shown in Figure 1.1. Research on fire and biodiversity in these landscapes has shown that, like all landscapes, there is a range of responses to fire. Some elements of the biodiversity are resilient to variation in fire regime, others are sensitive to fire intensity and/or sensitive to fire interval. Therefore, no single fire regime applied at landscape scales can meet the needs of any one major land management objective (e.g. biodiversity conservation), let alone multiple land management objectives.

4. Principles for information dissemination, technology transfer and capacity building

Communication is particularly important in rangelands fire management. The landscapes are extensive, population density generally low, and fires spread easily. People therefore need to cooperate with their neighbours in managing fire, and use a range of tools to detect, report and manage fire. Sharing information across tenures, regions, states and territories is important; effective fire management practice and policy requires better awareness and understanding of techniques and issues among fire managers and the broader community.

Important principles for knowledge sharing in the rangelands are:

- Establishing networks
- Respecting differing values
- Consultation
- Transferability

5. Criteria for setting priorities for development of fire management plans

All regional bodies in the rangelands will need to address fire management as part of the regional NRM planning process. The importance of fire within regions will vary, but even in the few rangeland regions where wildfire is relatively infrequent or restricted in its occurrence (e.g. chenopod shrublands), there will still be particular locations and contexts that demand a planned approach to fire management.

For fire management plans to be effective, there will need to be regional consideration of:

- Baseline (pre-European) fire history and biodiversity information
- Generality and transferability of results
- Community objectives and capacity, including those of Indigenous communities

6. Information requirements and critical knowledge gaps

Experience gained in undertaking various community-based fire management projects in northern Australia over the past decade (many of these involving NHT funding) has highlighted successful models of fire management, and knowledge gaps. While incomplete, that experience has much relevance to fire management in other regional communities in the rangelands.

Major knowledge gaps include fire history and fire mapping at enterprise and regional scales, fire risk assessment protocols, attributes of species, the role of changed fire regimes in apparent declines in biodiversity values (especially fauna) in some rangelands; methods of implementing mosaics of burnt and unburnt country for effective biodiversity conservation; protocols for the management of conflicting objectives, both across sectors (e.g. pastoral production, biodiversity conservation) and within sectors (controlling woody thickening; protecting fodder reserves); and the implementation of NRM plans, given logistical, social and institutional capacity and constraints.

In general, detailed studies of interactions between declining faunal species and fire regimes are a priority for rangeland fire research.

7. Appendix 1

A list of the IBRA Bioregions within the rangelands region with the percentage of native vegetation within that region

8. Appendix 2

List of information sources on species fire attributes and land use and fire maps for the major vegetation groups

Other resources

Databases produced in conjunction with this report:

- A bibliography of relevant reports and papers with key papers identified, and which can be sorted by vegetation type and other key words, has been produced in conjunction with this report and is available online from the Tropical CRC website at: <http://savanna.ntu.edu.au/publications/books_reports/fire_management.html>.
- Databases of current and recent fire management projects, funded by NHT and by other agencies (contact DEH for more details).

1. Why is fire management important in the rangelands?

1.1. Definitions

Rangelands can be defined as "land where livestock are grazed extensively on native vegetation, and where the rainfall is too low or erratic for agricultural cropping or improved pastures" (National Rangeland Management Working Group 1996). Australian rangelands cover about 5.5 million km^2, about 70% of Australia and include all or part of five jurisdictions (Queensland, NSW, SA, NT and WA). They range from arid and semi-arid areas in southern and central Australia to most parts of the wet-dry tropics across northern Australia, and include the slopes and plains of western NSW and southern Qld. The main vegetation types in the rangelands are native grasslands, shrublands, woodlands and open forests.

The extent of Australia's rangelands has been defined in the National Land and Water Resources Audit (ACRIS, 2001) as shown in Figure 1.2, and includes 53 bioregions based on the Interim Biogeographic Regionalisation of Australia (IBRA). The rangelands also correspond loosely to the region of extensive land use as defined in *Landscape Health in Australia* (Morgan, 2001). However, along the eastern periphery of the rangelands some bioregions are included in the intensive land use zone (Appendix 1, Table 7.1). In these regions cropping is a major land use and low percentages of native vegetation remain (due to extensive land clearing). IBRA sub-regions with less than 70% native vegetation will not be a major focus of the current report.

1.2. Importance of rangelands: Why management of rangelands is a national priority

Rangelands are important culturally, socially and historically for both Indigenous and non-Indigenous Australians. The economic interests in the rangelands include mining, tourism, meat and wool production. Small and emerging industries, including wild plant and animal products, are also significant.

The rangelands of Australia have a high biodiversity value: high species diversity, significant numbers of endemic species, areas of ecological and geo-morphological integrity, unique ecosystems and habitat for rare and endangered species.

Assessments of landscape health in Australia (Morgan, 2001) show that the rangelands are relatively intact with little clearing compared with the areas of intensive agriculture in eastern, southern and south western Australia. The rangelands are an important refuge for Australia's biodiversity. However, despite the relatively low level of disturbance in the rangelands, the abundance and richness of rangeland biodiversity is declining and there is evidence that inappropriate fire regimes are partly responsible. Therefore "understanding how fire affects biodiversity therefore has national significance" (Dyer et al. 2001).

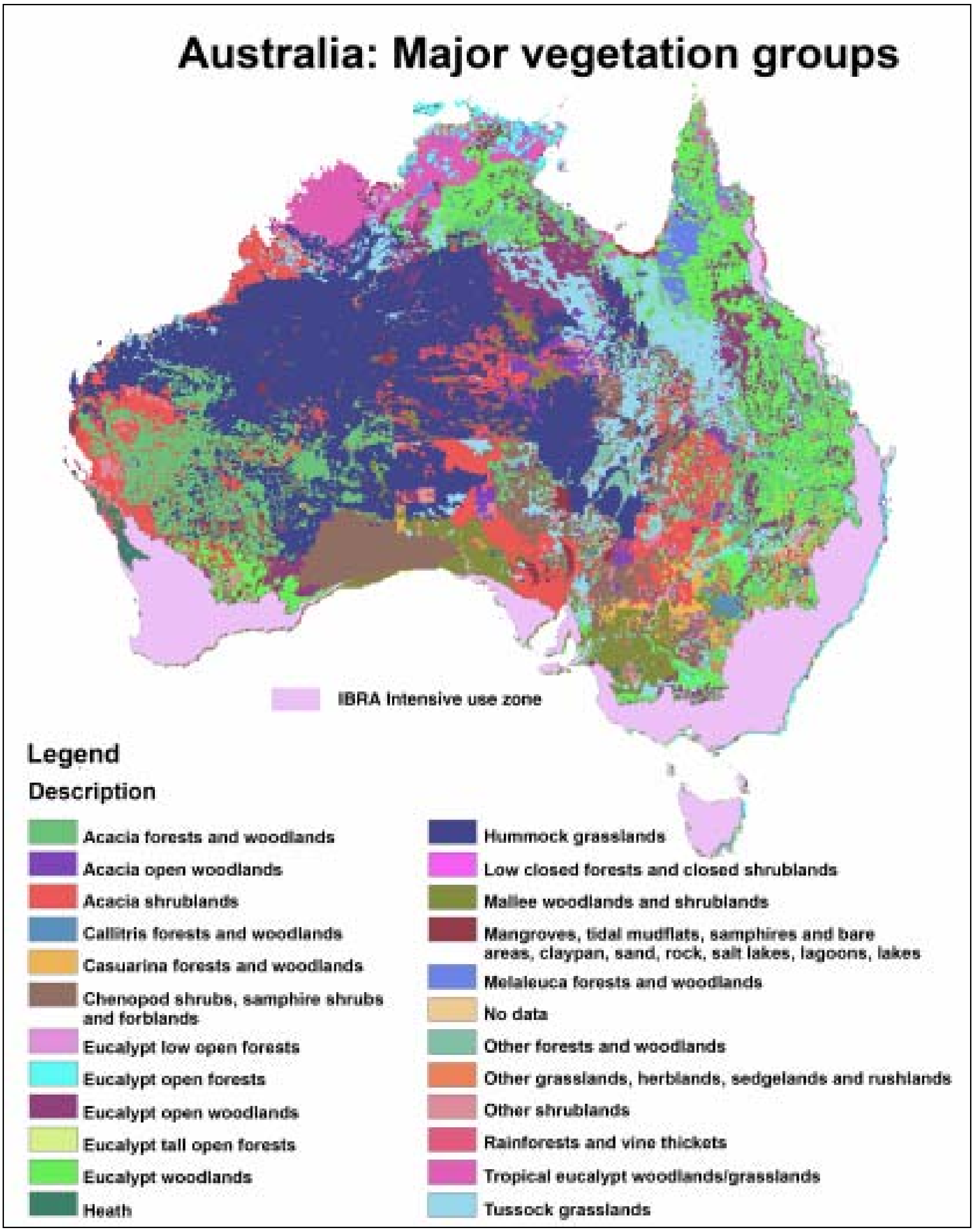

Figure 1.1 Main vegetation groups in Australia's rangelands

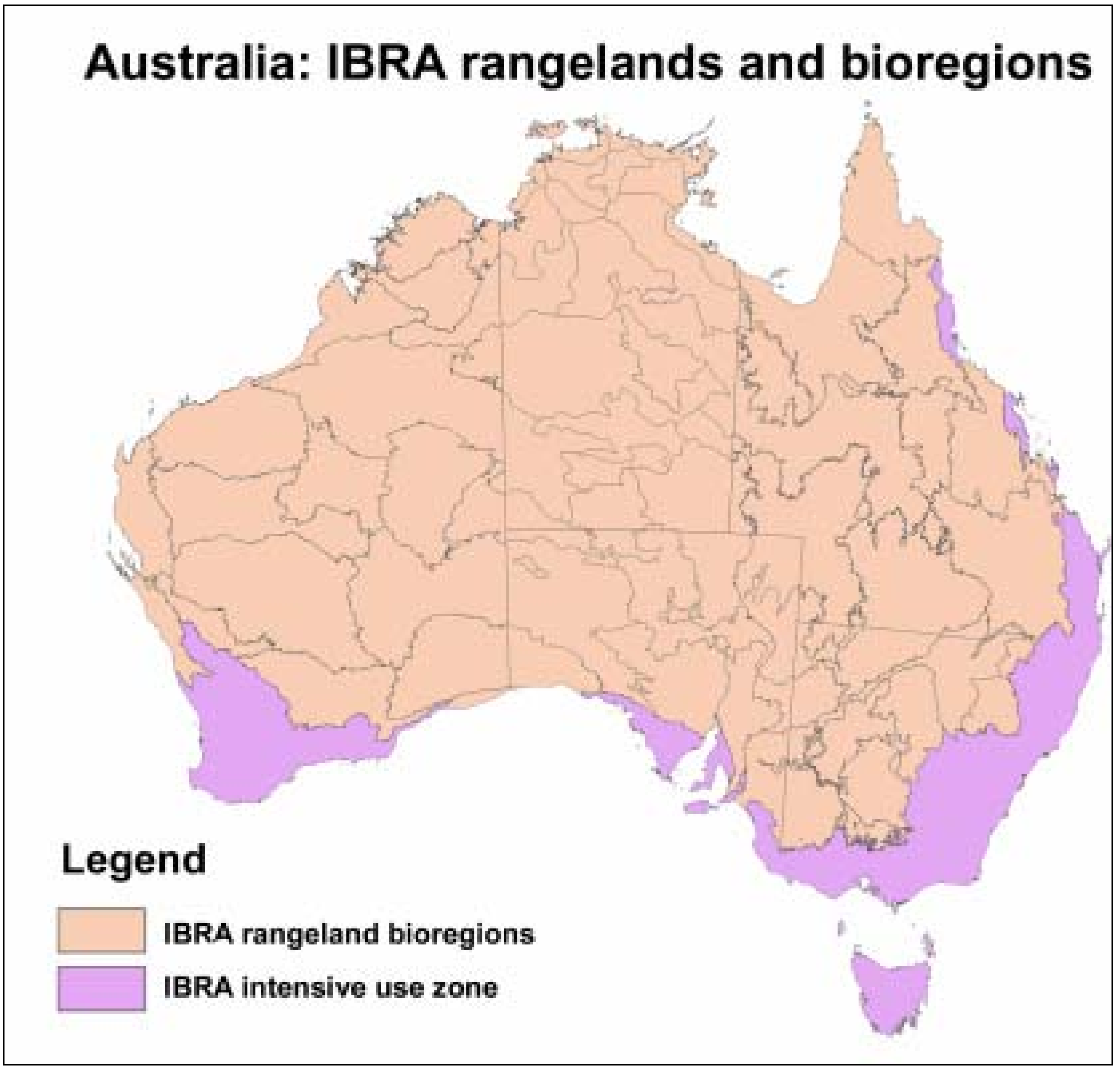

Figure 1.2 Intensive and extensive land use zones defined in Morgan (2001). Boundaries of IBRA regions shown within the extensive-use zone (NLWRA 2001, <www.nlwra.gov.au>

The Australian Government is committed to improving land management practices and protecting areas of high conservation significance in the rangelands. This commitment includes giving “priority funding under the NHT to projects in the rangelands which identify and protect areas of high conservation significance, improve fire management practices, and implement total grazing practices which conserve biodiversity and lead to more sustainable management of rangeland ecosystems” (Coalition Policy 2001).

1.3. Main threats to rangelands

Some past and current land management practices in rangelands have caused ecosystem degradation and reduction of productive capacity, including accelerated soil erosion, expansion of weed and feral animal populations, reduced water quality, increased soil salinity, decline in native plant communities and decreased biodiversity, particularly through impacts on threatened species, heritage areas and significant wetlands.

The major threats to the rangelands are through inappropriate land management, in particular, overgrazing and inappropriate fire regimes. Undesirable changes to fire regimes vary with location, e.g. many areas now have less spatial heterogeneity in burning pattern than is desirable, some areas have very infrequent fires others have very frequent or very large and intense fires. The areal extent of altered fire regimes has been identified as one of the key indicators for biodiversity in the State of the Environment report (Saunders et al 1998).

1.4. Fire as a land management tool in Australian rangelands

Fire plays an integral role as a disturbance throughout most of the rangelands. In the rangelands of northern Australia fires are frequent, and large areas are burnt every year. In the rangelands of central and southern Australia fires occur at approximately decadal intervals, following unusually wet years. The fires in the rangelands are more extensive than those of the more mesic and more densely populated areas beyond the rangelands in southern, eastern and south western Australia (Figure 1.3).

Fire, together with control of stocking rates (Fisher et al. 2004), is the major tool available for land management in the rangelands. The rangelands include a range of sectoral interests with different management objectives, such as government-managed reserves managed chiefly for biodiversity, pastoral lands managed chiefly for sustainable animal production, and Indigenous land managed for sustainable harvesting of resources (implying biodiversity conservation on a landscape scale) and for cultural and heritage purposes. The use of fire can be designed to meet a range of land management objectives within these sectors, such as, to maximise biodiversity, to protect fire sensitive habitats or culturally significant sites, to manage woody weeds, and to increase pastoral productivity.

The use of fire as a major land management tool in rangelands contrasts with the greater emphasis on suppression in the areas of more intensive agriculture and higher population densities outside the rangelands, where protection of life and property is of greater concern.

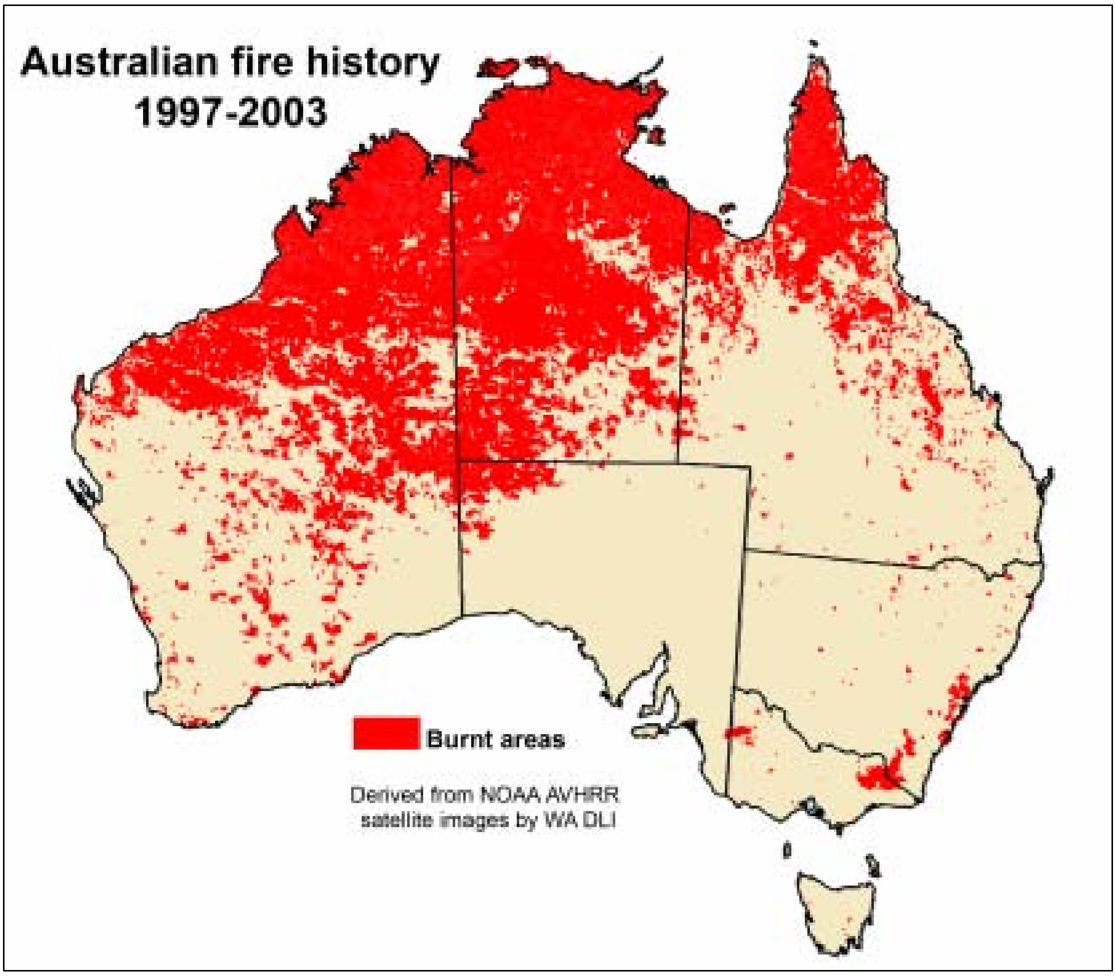

Figure 1.3 Australian fire history 1997–2003

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2. Fire management planning checklist

2.1. Background

The efficacy of regional NRM plans will be a function of the processes of development and implementation as well as their contents. In particular these processes include the formulation of the plan, implementation, monitoring of target outcomes and adaptation of the plan. The following checklist includes evaluation of all these stages with respect to the fire management component of the regional NRM plans.

The NRM plans for all the NHT regions within the rangelands will contain a fire management plan. Fire is a major factor shaping the rangelands and so requires considered management, even in those parts of the rangelands where fire is infrequent. The following checklist applies to the fire management component of the NRM plan for a NHT region.

Appropriate fire management varies with desired management outcomes, ecosystem type, climatic zone and state of ecosystem health. Fire management options for different vegetation types and climatic zones are discussed in Section 3.3. The scale at which the plan addresses fire management should be appropriate to the scale of the vegetation mosaic.

McDonald et al. (2003) described a framework for the evaluation of regional NRM plans in northern Australia designed to determine how well the major plan-making components reflect "desirable outcomes (savanna health criteria)" and to assess "the quality of information being used in these steps".

The following checklist aims to provide a structure and criteria for evaluating proposed fire management plans within NRM plans for NHT regions and subregions within the rangelands.

Reference

McDonald, G.T., McAlpine, C.A., Taylor, B.M. and Vagg, A.R. 2003, *Criteria and methods for evaluating regional plans in the tropical savannas. Stage 1* Report for Project 3.2.1, Bioregional Planning in the Tropical Savannas, CSIRO, Brisbane, 126 pp.

2.2. Fire management planning checklist

[Reference to other sections of this report, for further information, are noted in square brackets.]

1. *Planning process*
   - Has there been consultation with community groups and other stakeholders? [Sections 4.2, 6.1]
   - Have existing fire regimes, fire management practices and/or fire management targets been described? Where any of these are considered to be inappropriate, has the magnitude and direction of desired change been identified? [Sections 3.2, 6.2.1, Appendix 2]
   - Is there broad ownership of the fire management plan? [Sections 4.2, 4.3, 6.1]
   - Rural Fire Service or equivalent
   - Land holders / leaseholders—public and private
   - Land councils and indigenous communities
   - Other emergency services
   - Government departments e.g. main roads, transport
   - Private service providers e.g. railroads
   - Industry
2. *Components of the Fire Management Plan*

   (a) Information
   - Have vegetation types within the region been identified and described? [Section 3.3]

- Have sites of national environmental significance in the region been identified?
- Has information been assembled about species assemblages/ecosystems and species fire attributes in the region/subregion? [Appendix 2, Sections 3.2, 6.2]
- Has available information about species/ vegetation community response to various fire regimes been assembled? [Appendix 2, Section 6.2.4]
- Are fire history and current fire regimes documented for the region? [Appendix 2, 6.2.1]
- Are vegetation and land use maps of an appropriate scale to meet management targets? [Sections 3.3, 6.2.1, Appendix 2]
- Have available cadastral map data been accessed and used?
- Is above-mentioned information accessible?
- How is this information stored and retrieved?
- Who has long-term custodianship of the information?
- Is there evidence of specialist technical advice in the development of the fire management plan?
- Does the fire management plan show an awareness of the resources (key references) available? [Appendix 2, Sections 6.2.1, 6.2.2]
- Has there been thought given in relation to cultural and heritage values associated with plans i.e. with protection of sites of significance to Indigenous people and use of cultural knowledge and practices in resource management? [Bibliography—<http://savanna.ntu.edu.au/publications/books_reports/fire_management.html>

(b) Objectives and targets—developed through consultation

- Have fire management targets and associated resource condition targets been identified and described, with long- and short-term objectives?
- Is there evidence that the range of stakeholder aspirations and perceptions have been considered in the development of the fire management targets? [Sections 4.2, 4.3, 6.1.1]
- Have these targets been described at an appropriate scale? [Section 3.2]
- Do these targets meet the aspirations of all stakeholders? [Sections 4.2, 4.3]

(c) Options

- Have the limitations of recommended fire management practices been recognised? [Sections 5, 6.2.3]
- How do recommended fire management practices align with, or conflict with, other objectives and practices in the NRM plan for the region/sub-region?
- Are alternative fire management practices identified where necessary?

(d) Priorities

- Have fire management practices been evaluated in terms of cost/ benefit considerations? [Sections 5, 6.2.3]
- Have fire management targets been prioritised according to biodiversity conservation targets? [Sections 3.2, 6.2.4]
- Has consideration been given to sites of significance and those with heritage values for Indigenous peoples? [Section 5.1]

(e) Implementation

- Is fire management plan linked to maps of appropriate scale for implementation? [Section 3.2]
- Are the costings appropriate / realistic?
- Is there the capacity (motivation, expertise) to implement the recommended changes to fire management practices? [Sections 4.4, 6.1.1]
- Has the need for regional fire education been considered? [Sections 4.4, 6.3.1]

(f) Monitoring and review

- Does the fire management plan include monitoring of fire regimes at a property and regional scale to ensure proposed improvements in timing and intensity of burning are achieved? [Section 6.2]
- Will ecological values be monitored, including the responses of flora and fauna? [Section 6.3]
- How will fire regime and ecological monitoring be reported, assessed against management targets, and used to adapt the fire management plan in the future? [Section 6.3]

3. Fire ecology of rangeland ecosystems

3.1. Definitions

aerial control burning—ACB; strategic aerial burning operations undertaken from a helicopter or aeroplane to develop typically linear firebreaks, especially useful in remote and rugged terrain

annual plants—plants whose reproductive life cycles are completed within one year

backing fire—fire burning into the wind

back-burn—a backing fire often applied in fire control operations as a means for directing a relatively low-intensity fire into the path of an oncoming wildfire

biodiversity—diversity of flora and fauna within a region, assessed at various spatial and temporal scales

char height—the height of flames indicated by burnt, blackened *(*i.e. 'charred') leaves that remain on the tree or shrub

***curing state*—**the proportion (%) of brown dead matter to green living matter in the ground cover (grass and litter) fuel load

***fire behaviour*—**physical attributes of individual fires: height and depth of flames, rate of spread, intensity, size and shape of various burning fronts, and intensity

firebreak—any break, whether constructed or natural, which restricts a fire from spreading further.

fire intensity—the rate at which heat released from a linear section of the fire front usually expressed in units of kilowatts per metre of fire edge, kW/m

***fire regime*—**attributes of fires in any one region over a number of years including: extent, seasonality, frequency, intervals between fires, intensity, patchiness

fire scar—an area of burnt vegetation as mapped from aerial photography or satellite imagery

fire-sensitive species—plant species which are readily killed by fires. These typically comprise obligate seeder species, but also include a variety of less fire-hardy re-sprouters which may be susceptible to relatively low intensity fires

fire suppression—activities involved in the containment and eventual extinguishing of an unwanted fire

***fire weather*—**the combination of climatic conditions important for influencing fire behaviour, *i.e*. temperature, wind speed, relative humidity

***flaming combustion*—**the initial phase of the fire characterised by the rapid combustion of light fuels such as leaves, litter, grasses

***flanking fire*—**typically relatively low-intensity fires burning at right angles to the prevailing wind direction

fuel load—the amount of standing grass and litter fuel, usually expressed as oven-dry weight of fuel per unit area (e.g. tonnes per ha; kg per sq. m)

Geographic Information Systems (GIS)—computer based mapping software used for undertaking often complex landscape-scale assessments

***greenhouse gases*—**includes those gases emitted from fires, such as methane and nitrous oxide, which entrap incoming solar energy and thus enhance the process of atmospheric warming

heading fire—fires burning with the wind

heat yield—the heat output from burning fuels, measured in kilojoules per kilogram of dry fuel

hotspots—sites detected by thermal satellite sensors which are relatively hotter than surrounding areas, such as fire fronts

Landsat imagery—fine resolution satellite imagery (pixels 30 m x 30 m) used for fine-scale mapping of fire scars

line ignition—ignitions applied (typically with a drip torch) with a continuous line of fire along a fire front

litter—that component of the fuel load comprising dead leaves, small twigs, etc.

mesic savanna—savanna vegetation occurring in areas where long-term, mean annual rainfall is greater than 900 mm

mosaic burning—burning with the intention of creating small patches, resulting in a landscape characterised by habitat patches of different fire ages

NDVI (Normalised Difference Vegetation Index)—a measure of the 'greenness' of vegetation, derived from NOAA-AVHRR imagery.

NOAA-AVHRR imagery—coarse resolution imagery (pixels >1.1 sq. km) used for detecting hotspots, and also for mapping of fire scars at the broad regional scale [See Abbreviations and Acronyms, p. 1].

obligate seeder—plants which regenerate solely from seed held on the plant or in the soil after adults have been killed by fire

perennial plants—plants which live for two or more years

perimeter ignition—line ignitions which are lit on several sides of a burn area so that the fire is drawn into the centre as it develops

pixel—the minimum area detectable by a satellite sensor, e.g. 30 m x 30 m for Landsat ETM imagery; 1.1 sq. km for NOAA-AVHRR imagery

point ignition—fire ignited from a single point, as in aerial control burning

prescribed fire—any fire which is lit for management purposes

progressive burning—the practice of burning areas progressively throughout the year as fuels dry out

rate of spread—the speed with which the fire travels, typically measured as metres per second or kilometers per hour

re-sprouter—plants which possess the capacity to re-sprout from dormant buds on stems or from root bases following a fire

riparian vegetation—plant communities found within or adjacent to rivers and streams

rotational burning—process of burning different parts of a paddock or specified area sequentially over a number of years, typically using fires of different intensities

savanna health—measure of the degree to which a savanna ecosystem "maintains basic functions at all spatial scales, maintains viable populations of all native plants and animals at appropriate spatial and temporal scales, and, meets the long term needs (spiritual, aesthetic and material) of those with an interest in the savannas" (Whitehead et. al. 2000).

scorch height—height above ground which leaves in the canopy are killed by heat, and thus 'browned'

seed bank—reserve of seeds held either on the plant or in the soil. Soil seed banks of some species, especially legumes, may remain viable for decades

semi-arid savanna—savanna vegetation occurring in areas where long-term, mean annual rainfall is less than 900 mm

smoldering combustion—the phase of the fire following flaming combustion where heavier fuels such as sticks and logs are slowly consumed

species fire attribute—characteristics of a species that strongly effect the response of that species to various fire intensities and fire frequencies, particularly relating to survival and reproductive potential. For plant species, attributes mainly relate to seeding and re-sprouting biology.

strategic burning—the use of prescribed fire, including aerial control burning, to strategically breakup paddocks, properties or large regions

sustainability—continued long-term productivity of a management systems or continued long-term function and integrity of an ecosystem.

tactical firebreaks—includes the use of back-burning and grading operations undertaken in the course of fire suppression

wet season burning—use of prescribed fire during the wet season period to reduce fuel loads of annual grasses, especially *Sorghum spp*.

3.2. Principles

3.2.1. Fire regimes and fire ecology

Fires are recurrent disturbances in landscapes. Ecological effects are therefore shaped by fire regimes, namely the collective effects of fire frequency, intensity, season and type (Gill et al. 2002, Gill and Bradstock 2003). Spatial characteristics are also important.

The fire regime at any location reflects the sequence of individual fires that have occurred there, including the characteristics and timing of each fire. Fire regimes are determined by the human, physical and biological characteristics of the landscape—the chance of ignition, the chance of fire spreading across the landscape, plus weather and fuel characteristics. A spectrum of different fire regimes is possible in most ecosystems, reflecting differences in the number, size and circumstances (e.g. weather) of individual fires. The intervals between fires are an important component of fire regimes that are not necessarily apparent to the naked eye. Historical records of fire are therefore important (e.g. mapping fires using remote sensing) for documenting recurrent patterns of fire.

Management can affect fire regimes through alterations to rates of ignition, fuel quantity (e.g. by grazing) and spread of fires via prevention and suppression activities. The effects of different management activities and strategies on fire regimes are complex, incompletely known and dependent on local factors. Ignition sources vary—fires may start from lightning, or be deliberately or accidentally lit by people. Once started, the spread of fire depends on slope, fuel moisture, and weather (temperature, humidity, and wind). Fuels—the amount of fuel, its moisture content, height, continuity and composition—are important determinants of fire behaviour. Fuel loads need to be understood to assess the risk and potential intensity of wildfire or for planning prescribed burning.

At a landscape-scale each fire regime component will exhibit variation, and the nature of this variation will have important ecological consequences (Gill et al. 2002, Gill and Bradstock 2003). Spatial variation in fire regime components can be expressed in statistical terms (e.g. mean and variance of area or proportion of the landscape affected by differing levels of each component, Gill and Bradstock 2003).

3.2.2. Climate and fire regions/ syndromes

Fire regimes are driven by the interplay between landscape, climate and land use, not just climate. However, at the continental scale, we can recognize three major climate / fire regions:

The majority of Australia’s rangelands are located within the first two of these fire/climate regions.

- The wet–dry tropical savanna region of northern Australia, where landscape-scale fires can occur annually. Every wet season there is accumulation of fuels (mainly grasses and herbs) across the landscape. Every dry season, the fuels cure, and there are periods of moderate-to-extreme fire weather. Ignition can also occur every year, either by people or lightning. Fires in the savannas occur in the dry season months of May to November often continuing into December.
- The semi-arid and arid interior, where landscape-scale fires occur episodically, typically at intervals of up to decadal in the arid interior. Here, extensive fires only occur after periods of exceptional growth when continuity of fuel is increased by growth of annuals between spinifex hummocks, as a consequence of rare and unpredictable years of above-average rainfall. The hot, dry climate promotes curing of fuels every year. Fires in the arid interior usually occur in spring-summer (September–January).

- The southern temperate zone, where landscape-scale fires also occur episodically, and at intervals of decades. Here, landscape-scale fires are usually associated with forests, the fuels are woody rather than grassy, and major fires occur in rare years when drought and severe fire weather co-occur. Fires in the southern temperate forest regions typically occur in spring-autumn (October–March).

3.2.3. Biodiversity and species fire attributes

Biodiversity is literally the diversity of life. Factors that affect abundance and distribution of plants and animals inherently affect biodiversity. Climate, soils, and disturbance (including fire) influence the patterns of biodiversity across landscapes.

Biodiversity is affected by variation in fire regime (see *Fire regimes and fire ecology* above). Fire intensity and residence time may determine the proportion of individuals that survive a particular fire and also affect the regeneration processes, germination and re-sprouting. Many species require a minimum time (interval) between fires to re-establish their ability to regenerate after fire. The spatial scale of fires determine the scale of the resulting mosaic.

While fires may cause death of individual animals, the indirect effects are more critical for the persistence of a species in a given area. Fauna responds to variations in vegetative cover. Some species require relatively dense cover for shelter while others are favoured by more open conditions. Animals that depend on seeds for food may be strongly affected by fire regimes that cause changes in abundance and seeding of key plant species. Similarly, animals that use hollows in trees for shelter and nesting, will be affected by the density of hollows and their rates of formation and loss—processes that are sensitive to fire intensity and interval. Fire season may affect various biological responses to an individual fire event (e.g. flowering in plants, breeding in animals).

The effects of particular fire regimes may vary strongly between species because of contrasting species life history characteristics or attributes. An important species attribute is the ability of a species to re-sprout after fire, (re-sprouters), or dependence on seed for post-fire regeneration (seeders). Particular combinations of traits may represent functional types. A long-standing scheme exists for classifying the responses of plants to disturbance ('vital attributes'—Noble and Slatyer 1980, Noble and Gitay 1996). Similar schemes for animals are lacking (Whelan et al. 2002, Bradstock et al. 2004).

A key outcome of the vital attributes system is that differing functional types of plants will have differential sensitivity to recurrent disturbances such as fire (Noble and Slatyer 1980, Noble and Gitay 1996). Functional types that are most sensitive to disturbance are those in which established individuals (adults and juveniles) are prone to death by disturbance (i.e. seeders, with no capacity for vegetative recovery) and where seed banks may be exhausted by disturbance. In terms of fire, sensitive functional types of this kind will be characterized by species that exhibit a high probability of mortality of juveniles and adults irrespective of fire intensity, plus seedbank types where germination is strongly triggered by fire. Evidence suggests that such 'fire interval sensitive' species may be found in a wide range of Australian plant communities (e.g. Bradstock et al. 2002).

Similarly, some species are strongly affected by differing fire intensity ('fire-intensity sensitive' species). Obvious examples of such species include large arboreal mammals that rely on hollows for nesting. Such animals may suffer high mortality in high intensity fires but paradoxically are dependent on occasional high intensity fires for hollow formation.

Different species exhibit different tolerances across the spectrum of fire regimes according to their biology. Knowledge of these limits and the way they vary among the biota characteristic of any particular ecological community is of obvious significance for natural resource management.

The ecological effects of fire regimes require evaluation at landscape scale (see also the section on mosaics below). Within a fire regime there is spatial variability across most landscapes, even within the same ecological community. The variable nature of fire regimes across most landscapes constitutes an 'invisible mosaic' (Gill and Bradstock 2003, Gill et al. 2003) that can only be understood through compilation of adequate spatial records of fires over time. Mapping of the invisible mosaic allows the ecological responses of plants and animals to be interpreted at landscape scales. The key factor for biodiversity conservation is the degree or spatial extent of any adverse fire regimes (Gill et al. 2002, Bradstock and Kenny 2003). When fire regimes become adverse across the majority of the habitat of any given species in a landscape, a high chance of loss of that species from the entire landscape can result. Adverse fire regimes that are confined to a minor proportion of the habitat of any particular

species may result in localized losses but may have little effect on the persistence of that species across the entire landscape.

3.2.4. Mosaics

Vegetation and habitats exist naturally as mosaics in the landscape; for example, the inclusion of small acacia scrubs, cypress pine thickets, monsoon forest patches, riparian corridors, and swampy vegetation within a broader tropical eucalypt woodland savanna matrix. Maintaining the diversity and health of that matrix is obviously important for providing key resources for dependent fauna and flora; that is, for biodiversity generally. As an affecting process, fire has a special role in maintaining biodiversity throughout the landscape through its effects on habitat diversity and associated availability of resources—both through the creation of larger and smaller patches (i.e. spatially) and through the creation of shorter and longer fire intervals (i.e. temporally).

In general, even where optimal fire regimes for individual species are not known, a fire regime that provides variety and variability, preferably at a fine scale, is likely to provide for the greatest variety of species, by allowing individuals to choose areas that meet their various requirements. Equally important, in a fine-scale patchy mosaic of habitats there will always be populations that can colonise areas as the vegetation changes through time between fires. As a general rule, large areas of monotonous habitat, whether created by extensive frequent wildfire or total fire exclusion, are likely to cater for fewer species and lower abundance of many of those that are there, than would the same areas if they contained a variety of habitats generated by fire.

3.2.5. Management and sustainability

People have used fire as a land management tool in Australia for at least 50,000 years. The effects of management activities—be they prescribed fire or deliberate fire exclusion—need to be understood in the context of local and regional fire regimes. Different fire regimes can have different impacts on fuels, fodder or biodiversity by changing the composition of plant species and by altering habitats. Different land management goals may require the implementation of different fire regimes.

Because species responses to different components of fire regimes vary, and because differentially sensitive species are co-located in landscapes, then no single fire regime can optimise all biodiversity outcomes. Landscape level variability in all fire regime components (not just the ‘visible’ time since fire mosaic) is required. Appropriate yardsticks are required to define acceptable ranges of variability in fire regime components across landscapes on the basis of the biological attributes of resident species of plants and animals.

In some parts of Australia, information about functional traits of species has been used to derive biodiversity-oriented guidelines for fire management. For example, some species are sensitive to recurrent disturbance, and the length of time between individual disturbance events may be critical. For these species a minimum time between fires is needed for key processes such as maturation, the initiation of vegetative recovery and senescence. Knowledge of species fire attributes may indicate changes in species composition under particular fire regimes.

Richardson et al. (1994), van Wilgen and Scott (2001) and Bradstock and Kenny (2003) present examples of this approach where appropriate ‘domain’ of between-fire intervals has been derived from vital attribute analyses within plant communities. In these cases the ‘domain’ consisted of specified maximum and minimum intervals between fire. Thus recurrent fires at intervals within the domain were predicted to maintain the existing species complement, whereas intervals of lengths either shorter or longer were predicted to lead to the decline and loss of plant species belonging to sensitive functional types. van Wilgen and Scott (2001) have characterized the boundaries of such a domain as “Thresholds of Potential Concern” (TPC). Richardson et al. 1994, van Wilgen and Scott 2001 and Bradstock and Kenny (2003) have illustrated how TPC’s based on fire intervals may be applied in interactive management systems to examine the consequences of recurrent fire within temperate landscapes containing species-rich plant communities. Bond and Archibald (2003) have illustrated the history of development and wider significance of TPC approaches to management in relation to fire and other management factors. Where available and relevant, TPC style information may be used in decision-support capacity to predict the consequences of particular fire regimes that may result from management decisions.

Based on the above discussion, then, the following general principles provide a basis for the management of fire and biodiversity in landscapes.

- The ecological effects of fire are determined by fire regimes.
- Species of plants and animals have limits of tolerance to fire regimes, which can be exceeded under particular circumstances.
- Knowledge of the limits of tolerance to fire regimes (‘thresholds’), characteristic of particular plant communities can be used to predict the ecological effects of particular management strategies. The ecological outcomes of decisions made on this basis should be subsequently verified through appropriate monitoring.
- The floristic composition and physical structure of plant communities determine the quality of habitat for many animal species. Fire regime effects on plant communities therefore affect animals.
- Management guidelines developed for plant communities may be applicable to animals because of the importance of vegetation as habitat.
- Fire regimes are partly invisible because they are shaped by recurrent (past) events. A spatial fire history record is needed to describe the set of fire regimes that prevail in a landscape at any particular time.
- The effects of fire regimes in general, and adverse fire regimes in particular, need to be understood at broad spatial scales. In particular, management needs to address potential losses of species that may result from adverse fire regimes, at a landscape scale.
- The loss of a species from a landscape may occur when fire regimes that are detrimental to that species predominate across the bulk of its habitat in that landscape. In this sense, adverse fire regimes may act as a dynamic fragmentation process.

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3.3. Vegetation types

The main vegetation groups of the rangelands are:

- Tropical eucalypt forests and woodlands (savannas)
- Melaleuca woodlands
- Tussock grasslands
- Hummock grasslands
- Temperate eucalypt and open woodlands
- Acacia forests, woodlands, open woodlands and shrublands
- Chenopod shrubs, samphire, forblands
- Mallee eucalypt shrublands

Within each of these main vegetation groups there are patches of other vegetation types. Some of these types are fire sensitive (in terms of intensity and/or inter-fire interval) and so require different fire management to that of the surrounding dominant vegetation types. Examples include monsoon rainforest pockets within the tropical eucalypt savanna, and stands of *Callitris* within tropical eucalypt savanna, mallee or temperate eucalypt communities. Discussion of the fire management of these vegetation types of restricted distribution is included in the sections describing the main vegetation types.

These vegetation groups are described and fire management issues are discussed under the following headings:

- Biophysical overview
- Fire ecology [Refer to Section 3 for definitions of terms and concepts]
- Fire management
- Fire knowledge gaps [See also Section 6]
- Key references

Other resources are listed in Appendix 2, i.e. species fire attributes, and land use and fire maps.

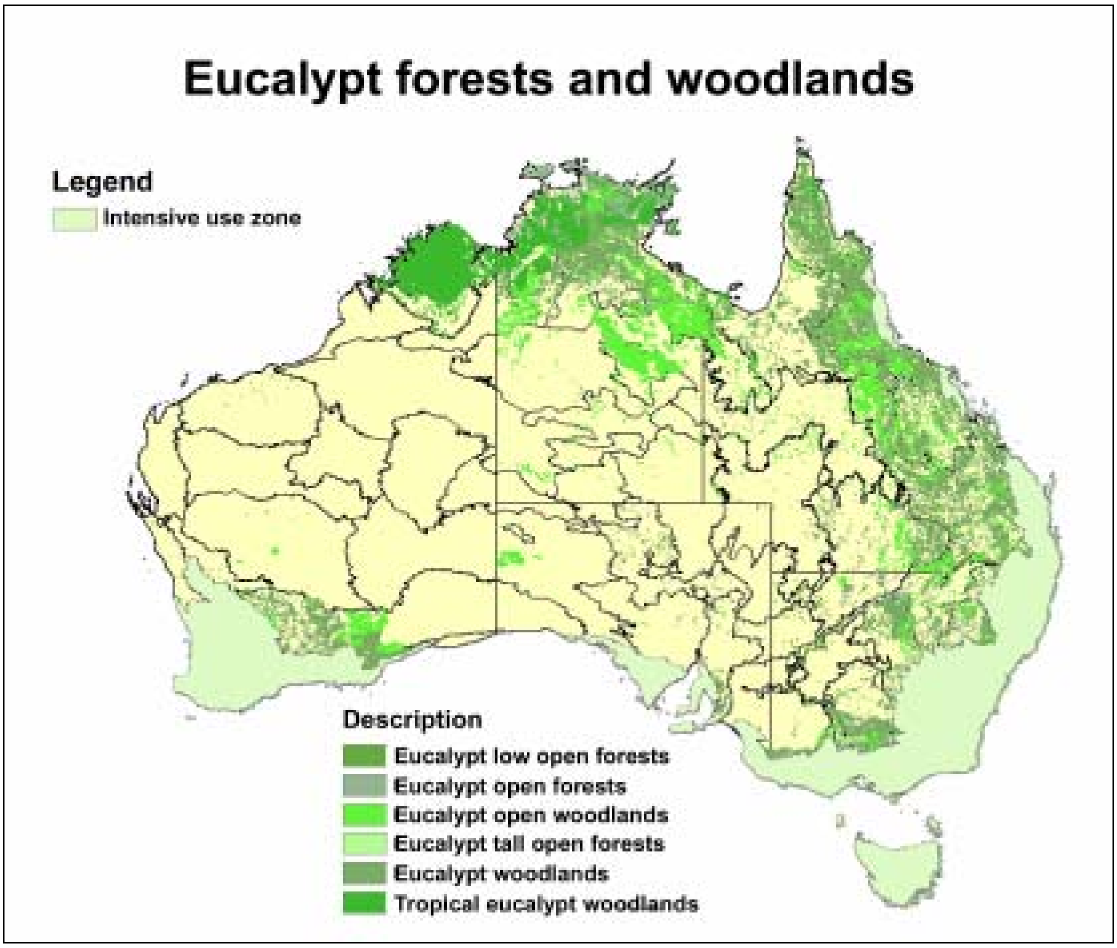

Figure 3.1 Distribution of eucalypt forests and woodlands (NLWRA 2001, < www.nlwra.gov.au>) Note that this section refers to these vegetation groups where they occur within the tropics

3.3.1. Tropical eucalypt forests and woodlands (savannas)

Biophysical overview

Tropical eucalypt forests and woodlands with a grassy understorey—or savannas—are the dominant vegetation type over several million square kilometres of northern Australia. They occur across the northern part of the continent, from Broome in WA to the northern half of the NT, and north Queensland. Their distribution extends from higher-rainfall, near-coastal areas to inland, semi-arid areas. Within their distribution there are three broad landforms:

- flat lowland plains, invariably with red sands and loams
- ‘stone country’ of rocky escarpments, with sandy or skeletal soils
- ‘black-soil plains’, with cracking clays

More detailed descriptions of tropical eucalypt savanna vegetation are found in Williams & Cook (2001a), Williams et al. (2002).

Australian tropical eucalypt savannas are invariably eucalypt open-forests and woodlands with a grassy understorey, but they vary considerably in composition and structure due to variation in annual rainfall and soil texture. Broad-leaf trees and shrubs such as *Terminalia* (billy goat plum), *Brachychiton* (kurrajong) and *Erythrophleum* (ironwood) may also occur in conjunction with the eucalypts in both the wetter and drier tropical eucalypt savannas. On heavy textured clay soils, there may be no trees.

Eucalypt savannas in the higher-rainfall areas, on the lighter textured soils, are usually open forest, typically dominated by eucalypts 10–25 m tall with a canopy cover of 40–60%. The understorey may consist of both tall annual or perennial tall-grasses. In the Kimberley (WA), Top End of the NT and Cape York (Qld), such forests are dominated by *Eucalyptus tetrodonta* (stringy bark) and *E. miniata*

(woolly butt); open Melaleuca forests (see Section 3.3.2) and some patches of monsoonal vine forest fringe the treeless floodplains. Heaths, with a few trees, and hummock grasses (spinifex) grow on the 'stone country'.

In the semi-arid regions, the tropical eucalypt savannas are woodlands and open woodlands. The eucalypts are shorter (5–15 m tall) and have less cover (5–30%), than those of the forests. There are numerous species that dominate, but common ones in north western Australia are bloodwoods and boxes, e.g. *E. tectifica* (grey box), *E. terminalis* (bloodwood) and *E. pruinosa* (silver box). Common species in north Queensland include the ironbarks and boxes, e.g. *E. crebra* (narrow-leaved ironbark), *E. melanophloia* (silver-leaved ironbark), and *E. brownii* (Reid River box), and bloodwoods e.g. *E. erythrophloia* (red bloodwood). Perennial grasses here include kangaroo grass, black spear, ribbon and white grass on the lighter textured soils. On the poorest and most shallow soils in the lower rainfall areas, tree cover is sparse (1–2%) and spinifex (*Triodia* spp.) predominates.

Some *Acacia*-dominated woodlands provide the exception to the rule of eucalypt predominance in northern Australia. Notable examples are the extensive areas of brigalow open forest (*A. harpophylla*) on clay soils in eastern Queensland, large areas of which have been cleared and sown with pasture grasses such as buffel and rhodes grass; lancewood (*A. shirleyi*) on lateritic soils of the Sturt Plateau in the Northern Territory, and pindan (*A. eriopoda* and *A. tumida*) on sandy soils in the Dampierland region of Western Australia. Woodlands and open-woodlands dominated by gidgee (*A. cambagei* and *A. georginae*) also occupy substantial areas of fine-textured soils in central and western Queensland (see Section 3.3.6).

There are many different types of tropical eucalypt savanna, and the savanna region has a rich flora and fauna. Within the savanna region, other vegetation types occur, such as monsoon rainforest, heathlands, *Callitris* woodlands, floodplain grasslands and melaleuca forests. These patches may vary in size from hectares to hundreds of square kilometres.

Fire ecology

Fire has influenced the nature of the tropical eucalypt savannas over the course of their evolution (Williams and Cook 2001b). Fire is frequent and extensive in this vegetation type, and most fires in Australia occur in the tropical eucalypt savanna region. The fire regime is driven by the highly seasonal onsoonal climate. There is a hot wet season (November–March) and long, warm dry season (April–October). Grasses grow during the wet season, which then cure during the dry season, and the trees continually drop leaf litter throughout the dry season. Dry thunderstorms during the late dry season/early wet season result in lightning. This wet–dry-lightning cycle occurs every year, creating the potential landscape conditions for frequent and extensive fire over evolutionary time.

Fires can occur from March to December. Prior to the arrival of people, fires would have been concentrated in the October–December period, when lighting and dry fuels coincided. At present, most fires occur in the dry season (April–October). Fires in the late dry season (August–October) are usually more extensive and intense than those in the early dry season, because fire weather becomes more extreme as the dry season progresses, and the landscape is drier.

Research on fire ecology and landscape management in the tropical eucalypt savannas has addressed fire behaviour, the effects of fire on nutrient dynamics, the dynamics of savanna-rainforest interactions, and responses of savanna vegetation and fauna. Research has been undertaken on conservation, pastoral, mining and Aboriginal lands.

Biodiversity is a major resource of the tropical eucalypt savannas, on all land tenures. The effects of fire on biodiversity—both flora and fauna—have been researched for a number of savanna types, including both the mesic (wetter) savannas and the semi-arid savannas (Russell-Smith 2001; Williams et al. 2002, 2003). There have also been studies of fire impacts on biodiversity in the non-woodland vegetation types within the tropical eucalypt savannas, such as monsoon rainforests, heathlands, tussock grasslands. The major fire-biodiversity projects that have been undertaken in the tropical eucalypt savannas are summarised in Williams et al. (2003).

Research on fire and biodiversity has shown that, like all landscapes, there is a range of responses to fire. Some elements of the biodiversity are resilient to variation in fire regime, others are sensitive to fire intensity, and others are sensitive to fire interval (fire frequency). For example, over the course of the Kapalga Fire Experiment, overall plant diversity, a number invertebrates and some herpetofauna (lizards, etc.) responded more to year-to-year variation in rainfall than to fire regime (Andersen et al.

2003). Tree density is sensitive to fire intensity. Heath vegetation (which is rich in obligate seeder species), some plant-processes (seedling recruitment in the dominant eucalypts), and the abundance of some faunal groups (small mammals), appear to be sensitive to variations in frequency of fire, in particular intervals between fires. At Solar Village, near Darwin, for example, a significant proportion of the fauna were clearly favoured by long-unburnt conditions. Possums and tree rats require tree hollows and shrubby understorey, and the abundance of these habitat elements increases with time since fire (Woinarski et al. 2004).

A particularly important ecological principle for fauna, is that landscape patchiness in both space and time—the mix of rich and poor sites, burnt and unburnt country, periods when food resources are plentiful, spatial variation in the intervals between fires—is extremely important for community and population dynamics. This is true in both savanna and non-savanna landscapes.

Animals can move to track this variation in patchiness. Such responses vary in complexity, from kites, which follow individual fires during combustion, to quails, that nest in recently burnt country (Woinarski and Recher 1997), and the partridge pigeon, which requires a mix of burnt and unburnt country at the scale of the home range (hectares; Fraser et al. 2003).

Fire management

Indigenous people have lived in the tropical eucalypt savannas, and used fire to manage the landscape, for at least 50,000 years. Indigenous and non-Indigenous people continue to use fire for many types of land management purposes. However, there have been many changes to the fire regimes—the extent, frequency, severity and timing of fires—over evolutionary, pre-historic and contemporary times.

Major land uses within the tropical eucalypt savannas include pastoralism, biodiversity conservation, mining, tourism and recreation, and wildlife harvesting by Aboriginal people. Land tenure is largely pastoral lease and Aboriginal freehold. At present, fire is integral to the management of land across all these sectors and land uses in the savannas. A major management concern is the occurrence of extensive, frequent (annual-biennial) and intense fires late in the dry season, with a range of ignition sources including lightning strikes and man’s activities.

It is becoming increasingly apparent that an important management objective for biodiversity conservation in the savannas is to keep some of the savanna fire-free for intervals of the order of five years. At present, very little (<1%) of the landscape is left fire-free for such intervals. However, there is no agreement as to where such patches of unburnt country should be located, and the operational and institutional process by which such targets may be met. This is a major knowledge gap.

Given the variability between species and vegetation types in responses to fire, no single fire regime can meet the needs of management for multiple purposes including biodiversity conservation, even within the one savanna type. Thus, developing and implementing a regional fire regime management plan that meets the needs of sustainable production and biodiversity conservation is a major issue for the savanna region.

The capacity to manage fire, especially for multiple objectives, varies between regions and communities. Capacity ranges from those areas that have the resources and technical ability to implement aerial control burning (ACB) (e.g. some national parks, many rural fire management regions, individual pastoral enterprises) to virtually nothing in some pastoral enterprises and Aboriginal communities. [See also discussion of capacity building in Section 4.]

A key issue to be addressed for fire management in the savanna rangelands is the management of fire sensitive vegetation at landscape scales. Some vegetation assemblages, with restricted distribution within the broader extent of tropical eucalypt woodlands and open forests, are fire sensitive and require different management to the surrounding eucalypt-dominated savanna. These vegetation assemblages include rainforest, cypress woodlands, heathlands and wetlands (Dyer et al. 2001).

For monsoon rainforest, there is generally a decline in extent with the current regime of prevalent late dry season fire in north-west Australia (Russell-Smith and Stanton 2002). However, recent expansion of rainforest into eucalypt savanna has been documented for both the wet–dry tropics (e.g. Bowman et al. 2001) and the wet tropics (e.g. Harrington and Sanderson 1994). Changes in the extent and integrity of monsoon rainforest patches will have significant impacts on mobile faunal species that use rainforest resources, especially frugivorous birds (Whitehead et al. 2002).

Callitris is an obligate seeder and adult trees are killed by 100% crown scorch. Current regimes of frequent (annual-biennial) intense late dry season fires are causing declines in the extent of this vegetation type (Price and Bowman 1995).

Within heath vegetation, the obligate seeder shrubs are declining because of current frequent extensive late dry season fires in Arnhem Land and elsewhere (Russell-Smith et al. 2002).

Within savannas, wetlands are important for pastoral production, traditional Indigenous usage, biodiversity conservation and tourism (e.g. Townsend 2003; Whitehead et al. 2003). The re-establishment or maintenance of customary indigenous burning practices is probably the best management option for these systems, as this is likely to meet a variety of local and regional needs (Whitehead et al. 2003).

Other key issues to be addressed for fire management in the savanna rangelands include the following:

- Woody thickening. Since European settlement, there have been increases in the density of trees and shrubs associated with less frequent and less intense burning in grasslands and woodlands across northern Australia. This is largely due to the deliberate exclusion of fire and the reduction in fuel loads resulting from grazing (Dyer et al. 2001).
- Implementing and monitoring the effectiveness of mosaic landscape fire.
- The role of changing fire regimes in faunal declines (Woinarski et al. 2001).
- Fire abatement (reducing annual area burnt).
- The role of fire management in greenhouse gas abatement.

Fire knowledge gaps

Research on fire and landscape management within the savannas has addressed fire behaviour; responses of biodiversity and ecological processes to variation in fire regime; mapping fire history. Research has been undertaken on Aboriginal, pastoral and conservation lands. A major management concern has traditionally been the prevention of extensive intense late dry season fires, with an emphasis on fuel reduction to achieve abatement of the impacts of fire intensity on biodiversity values. However, it is becoming increasingly apparent that fire frequency is also important in the savannas, with many elements of the biodiversity and ecological processes sensitive to fire interval. More research is needed on the sensitivity of landscapes to variation in fire interval.

Major knowledge gaps include: the conduits and barriers to fire spread at landscape scales in remote lands, the response(s) of fauna to variation in fire regime; ways to keep patches of savanna unburnt at landscape scales for periods of about five years; protocols for implementing fire management programs on Aboriginal land; appropriate fire regimes in tropical grasslands; the carbon sequestration capacity of savannas, and the sensitivity of this capacity to variation in land use; the transferability of remote sensing fire history products into management programs.

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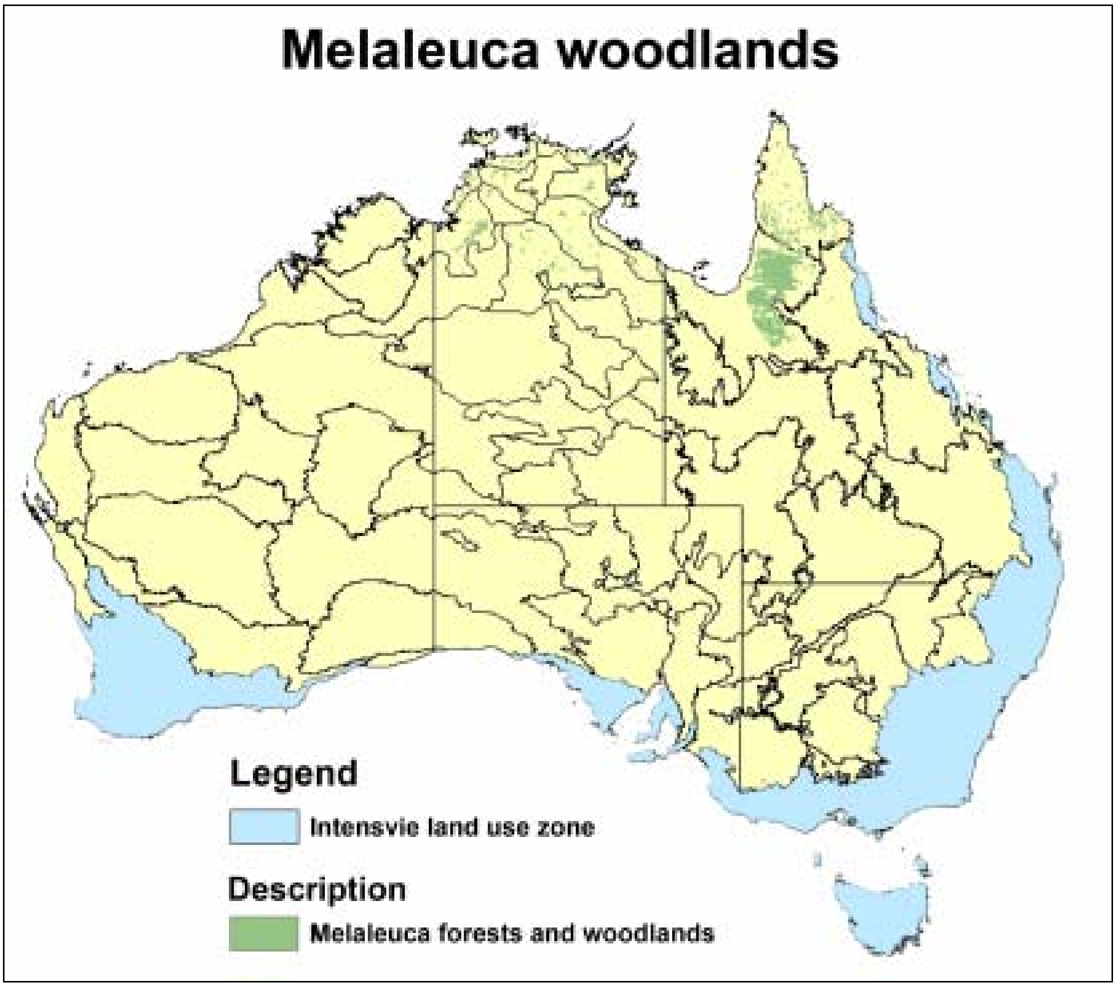

Figure 3.2 Distribution of Melaleuca woodlands, NLWRA 2001 <www.nlwra.gov.au>

3.3.2. Melaleuca woodlands

Biophysical overview

Forests and woodlands dominated by *Melaleuca* spp. (paperbarks) occur primarily in the rangelands of monsoonal northern Australia, with the largest areas on Cape York Peninsula and adjacent to the Gulf of Carpentaria in Queensland, and smaller areas in the Northern Territory and Western Australia. There are also small pockets along the subtropical and temperate coasts of Queensland, New South Wales and Western Australia, but these are outside the rangelands.

In the rangelands there are two broad types of melaleuca formation. Melaleuca grassy low woodlands are the more widespread of the two. They occur on flat to undulating alluvium or sandplains across northern Australia. The most extensive are the *M. viridiflora* (broad-leaved paperbark) grassy low open woodlands which dominate in Cape York Peninsula and coastal Northern Territory and are more scattered across the remainder of northern Australia. Their ground layer varies from sparse to dense, and is dominated by a wide range of tussock grasses. *M. minutifolia* (paperbark) low woodlands with *Sorghum* spp. tussock grasses form an extensive band in the northwest Northern Territory, southeast of the Joseph Bonaparte Gulf.

'Paperbark forest'—the other broad vegetation group dominated by *Melaleuca* spp.—is restricted to floodplains and swamps in coastal Northern Territory and north Queensland. Species include *M. leucadendra* (weeping paperbark), *M. argentea* (silver paperbark), *M. viridiflora* (broad-leaved paperbark), *M. fluviatilis* and *M. cajuputi*, which frequently occur with numerous other trees including deciduous vine forest and vine thicket species such as figs. Shrubs are often absent and the ground layer is a variable mixture of grasses, sedges and ferns.

Only 3% of the total area of all melaleuca forests and woodlands have been cleared or drained, mostly in coastal areas outside the rangelands. The remoteness of the monsoonal melaleuca forests and woodlands and their comparatively harsh site conditions, particularly during seasonal inundation, have generally protected them from clearing and other major changes. Tenure is largely pastoral leasehold and Aboriginal freehold, with some in protected areas. Most of the woodlands are grazed by cattle. Feral pigs are also widespread and abundant, particularly in the paperbark forests and the woodlands around the Gulf of Carpentaria. Their trampling and rooting activities cause serious erosion and silting of seasonally inundated areas. Feral water buffalo are uncommon in Queensland but are abundant in the floodplains of eastern Arnhem Land in the Northern Territory, where their grazing, trampling and wallowing activities can also cause erosion, silting, and changes to flow regimes. Feral horses are also plentiful in some areas of paperbark forest and woodland.

Fire ecology

As with other tropical savannas, the melaleuca grassy low woodlands support frequent and extensive fires, with a regime driven by the monsoonal climate in which they occur and the flammability of their grassy understorey. The wet season (which usually starts in November or December and continues until March) generates heavy growth of grasses and other herbs which dry out during the long dry season into tinder-dry fuels for fires. Thunderstorms during the build-up to the next wet season produce lightning that inevitably starts some fires. People start a lot of fires too, which frequently burn out of control across vast areas where fuel loads have accumulated. In the relatively high rainfall areas where most melaleuca forests and woodlands occur, 50–70% of the landscape may be burnt every year.

Where the dominant land use is pastoralism, however, fires are often suppressed to protect feed reserves. This can lead to a decrease in fire frequency and extent. In addition, cattle reduce fuel loads by eating grass, which further reduces the intensity of the fires that do burn. However, wildfires may still consume vast tracts of country during years when severe dry seasons follow big wets, resulting in highly combustible combination of high fuel loads and intense fire weather by the end of the dry. These sorts of changes in fire regimes are evident on Cape York Peninsula, where the most extensive melaleuca low grassy woodlands occur. They are also believed to be the main reason for woody thickening in these grassy woodlands.

Several studies have shown that *M. viridiflora* is increasing in density in woodland sites on Cape York Peninsula, and invading some sites that were previously open grassland. Explorers' records indicate that Aboriginal people used to light small fires throughout the year, and that burning frequency was particularly high in the grasslands and grassy woodlands around the Gulf of Carpentaria. Pastoralists burn frequently too, though not generally throughout the year. Instead most of their burning is confined to a short period early in the dry season, to provide firebreaks and green-pick. This, plus the reduction of grass fuel loads by cattle grazing, means most deliberate pastoral fires in Melaleuca woodlands are now of low intensity and inadequate to maintain the open nature of the grassy woodlands. Fires are seldom lit deliberately late in the dry season, even though this is the best time to control woody thickening, because they are too difficult to control and there is too much uncertainty about when there will be sufficient rain to stimulate new grass growth. Extensive wildfires sometimes occur late in the dry season, but they do not appear to be hot or frequent enough to suppress woody suckers in melaleuca grassy woodlands.

Far less has been published about the fire ecology of the paperbark forests associated with rivers, lagoons and swamps in northern Australia, but it can be assumed that their close association with permanent wetlands protects them from incursions by all but the most severe fires, in all but the driest of seasons. Their vine forest elements would be the species most likely to suffer from such incursions though the deciduous nature of many vine forest species in the late dry season may afford them some protection. The risk of fire incursions into these wetter melaleuca formations may be exacerbated by disturbance, however, such as occurs near the rural-urban interface of Darwin. There the establishment of the exotic, highly flammable gamba grass (*Andropogon gayanus*) on flood plain margins and wetter melaleuca woodlands is enhanced by soil disturbance. Even in more remote locations soil disturbance caused by feral pigs and water buffaloes may promote changes in vegetation structure or composition which could increase the flammability of the paperbark forests, but data are lacking.

Fire management

Current fire regimes in melaleuca grassy woodlands have negative impacts on both production and conservation values.

From a production viewpoint, the most immediate problem caused by woody thickening for many pastoralists is reduced visibility and control of cattle during mustering operations. In addition, woody thickening resulting from decreased fire intensities will inevitably lead to a reduction of forage for livestock. While there may be short term benefits if decreased fire intensities promote perennial grasses such as *Sorghum plumosum* over annuals such as fire grass (*Schizachyrium* spp.), few pastoralists would dispute the fact that the long-term outcome of woody thickening is reduced forage availability overall.

From a conservation viewpoint, changed fire regimes leading to woody thickening by melaleucas on Cape York Peninsula have been implicated in the decline of threatened granivorous birds such as the golden-shouldered parrot, star finch, Gouldian finch, buff-breasted button-quail and black-faced woodswallow. Increased densities of woody plants has led to more successful predation by birds such as pied butcherbirds and loss of perennial grasses such as cockatoo grass (*Alloteropsis semialata*) which seed-eating birds rely on for food at critical periods of the year. However, woody thickening is not the only threat to declining granivorous birds. Continuity of food supply is also critical, and this is most likely to be maintained if there is a fine-scale mosaic of areas burnt at different times throughout the year. This is because many granivorous birds eat mainly grass seeds that have fallen to the ground. Foraging is difficult in areas of dense grass, but far easier where patchy fires have removed grass bulk. However, intense, extensive late season fires not only remove the grass bulk but also destroy most of the fallen seed over areas far greater than the birds' home range. Thus the optimal fire regime for these species is one that controls woody thickening *and* retains a fine-grained mosaic of areas burnt at different times of year to ensure year-round food availability.

Appropriate use of fire may also be viewed by Indigenous people as being a paramount reason for people to stay on and manage country. For example, undesirable fire regimes in south-east Arnhem Land were the main reason for developing the community ranger program in Ngukurr. Traditional Owners were noticing that changed fire regimes on their country were leading to a reduction in flora and fauna productivity, and inferring that people's 'lonely country' was not being managed properly. From an Indigenous point of view, having people in the landscape impacts on social, economic, cultural and environmental aspects of country; and people are needed in the landscape to manage fire properly.

Fire knowledge gaps

Though it is possible to speculate about the impact of fires on the restricted paperbark forests associated with swamps, lagoons and rivers, there is almost nothing documented about their fire ecology or management.

Much more is known about the role of fire in woody thickening of melaleuca grassy woodlands and associated grasslands. However, there is poor understanding of how to actually implement improved fire regimes to control woody thickening. The aim is to conduct controlled burns that give grasses a competitive advantage over melaleuca suckers. This means burning at the hottest, driest time of year, which poses considerable risk to life and property.

From a pastoral perspective, it also carries the risk of destruction of vital feed reserves for livestock if the wet season rains are late. Pastoral managers need to know how to use livestock to manipulate fuel loads without compromising production, how to conduct controlled burns when fire danger is high, and how to manage the timing of late dry season fires to minimise impacts on feed reserves.

Interactions between fuel loads and livestock are of less concern to conservation managers, but the same issues of how to effectively implement inherently dangerous fire regimes apply. Conservation managers also need to know more about how to implement year-round patch-burning regimes that maintain food reserves for threatened grass-seed-eating birds.

Across the savannas generally, Indigenous people have much to offer in terms of knowledge about using fire, but much of the detailed knowledge in relation to use of fire in customary circumstances is somewhat reduced due to an inability of people to remain on their country, reducing this knowledge base. However this does not mean that Indigenous people do not have knowledge about use of fire, it is just that knowledge is changed, and it can be argued that knowledge is not static and is ever changing.

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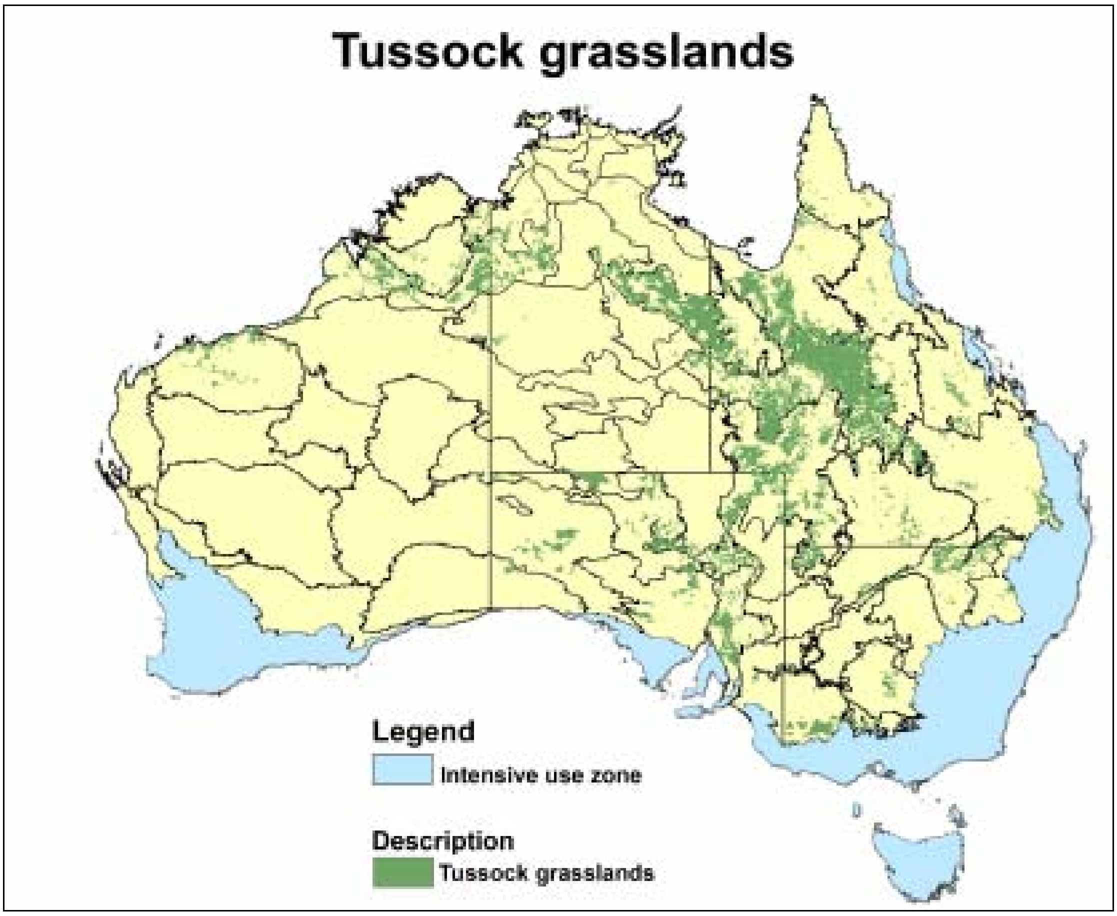

Figure 3.3 Distribution of tussock grasslands, NLWRA 2001< www.nlwra.gov.au >

3.3.3. Tussock grasslands

Biophysical overview

Tussock grasslands include a broad range of native grasslands extending from tropical to temperate Australia. The major distributions occur in western Queensland, central Northern Territory and throughout South Australia, though the largest area (nearly 300,000 km^2) occurs in Queensland.

Mitchell grasslands: tropical and sub-tropical, semi-arid to arid, tussock grasslands

The most extensive tussock grasslands are the Mitchell grasslands, which dominate the Mitchell Grass Downs bioregion of Queensland and the Northern Territory, and provide some of Australia's most valuable areas for rangeland pastoralism. They occur on broad, extensive cracking clay plains right across semi-arid tropical Australia, and extend south into the Darling River floodplain in northwest New South Wales, and the Channel Country of southern Queensland and northeast South Australia. They are dominated by *Astrebla* spp. (Mitchell grasses) though a range of other grasses and forbs is usually present, and shorter tussock grasses including bottle washers (*Enneapogon* spp.) and wiregrasses (*Aristida* spp.) may replace them on drier and stonier parts of the clay plains. The wiregrasses, Feathertop (*Aristida* latifolia) and white speargrass (*A. leptopoda*) may also increase after flooding. Under heavy grazing annuals such as Flinders grass (*Iseilema* spp.) become more prominent. Entire landscapes are dominated by Mitchell grasslands in the north, but vegetation types are more mixed in the south, with areas of open Mitchell grassland interspersed with woodlands on shallow soils and ridges. Low trees and shrubs are sometimes present within the grasslands, including gidgee (*Acacia cambagei*) in Queensland and *Terminalia* spp. in the Kimberley. The introduced wattle species *Acacia farnesiana* and *A. nilotica* have invaded large areas of Mitchell grass downs, where they now form a conspicuous woody layer in previously open grassland.

Bluegrass grasslands: tropical, sub-humid, tussock grasslands

North of the Mitchell grasslands lie the Bluegrass (*Dichanthium* spp.) tussock grasslands, which occur on the cracking clay plains and floodplains nearer the coast, where rainfall is higher. They reach their greatest extent on the floodplains associated with the Gulf of Carpentaria, Victoria River, Fitzroy River and the Ord River. *Chrysopogon fallax* (ribbon, or golden beard grass) and Flinders grass (*Iseilema vaginiflorum*) are common co-dominates.

Other tropical, sub-humid to humid, tussock grasslands

Wild rice (*Oryza australiensis*) dominates in seasonally flooded tropical grasslands, while mixed species tussock grassland and sedgeland, often with emergent *Pandanus* spp., occurs on plains associated with major rivers and swamps around the northern coastline. Other grasslands of variable composition occur on areas of heavier or seasonally inundated soils interspersed with grassy eucalypt and melaleuca savannas on lighter soils; their composition usually resembles the understorey of the neighbouring grassy woodland. They are especially common on Cape York Peninsula, where many patches are succumbing to shrub encroachment.

Temperate, semi-arid and arid, tussock grasslands

Tussock grasslands of variable composition are also widespread in arid and semi-arid South Australia and western New South Wales, usually in association with acacia and chenopod shrublands, hummock grasslands and other vegetation types, rather than in extensive tracts. Prominent species include Mitchell grasses (*Astrebla* spp.) on the alluvial cracking clay plains of the Channel Country and riverine plains, wanderrie grass (*Eriachne* spp.) on the stony ranges and plains of northern South Australia, spear grass (*Austrostipa* spp.) and wallaby grass (*Danthonia* spp.) in the hills and footslopes of the Flinders Ranges. Bottlewashers (*Enneapogon* spp.), love grasses (*Eragrostis* spp.) and wire grasses (*Aristida* spp.) are common associates of the acacia shrublands.

Temperate, subhumid, tussock grasslands

The tussock grasslands of the subhumid temperate areas in New South Wales, Victoria and Tasmania are among the most endangered ecosystems in Australia. Many of them have been cleared for cropping and exotic pastures, and those that have not been cleared have been greatly modified by intensive grazing. However, they mostly occur outside the rangelands and are not dealt with further.

Fire ecology

Fire regimes differ markedly between tropical and temperate grasslands, as does the use of fire as a management tool. In both cases, however, fires are now less frequent and less patchy than those lit by Aboriginal people prior to European settlement. Tropical grasslands experience major fire seasons most years. Hence they experience frequent fires unless fires are actively suppressed to protect pastures, and/or grassy fuel loads are depleted by grazing. Even where fire suppression is practised, the inevitably of fire seasons means that wildfires still occur, and fire is widely used as a management tool. Temperate grasslands experience major fire seasons at long and irregular intervals, following sequences of above-average rainfall seasons that produce abundant herbage fuels. Hence they seldom experience optimal conditions for fires to spread, and near-total fire exclusion is possible because fuel loads are generally kept low by year-round grazing.

Both temperate and tropical grasslands are prone to woody thickening and encroachment, if interactions between fire and grazing are not carefully managed. This is because the balance between trees, shrubs and grasses is dynamic, and the balance changes in response to seasonal conditions, fire and grazing. Reduced incidence and intensity of burning, as a result of deliberate fire exclusion and/or lowering of fuel loads by grazing, allows woody plants to become firmly established in grasslands.

In tropical grasslands common forms of woody thickening include: melaleuca encroachment into seasonally inundated grasslands; encroachment of native small tree and shrub species such as native rosewood (*Terminalia volucris*), bauhinia (*Lysiphyllum cunninghamii*) and gutta-percha (*Exocaria parviflora*) into more fertile bluegrass and Mitchell grass pastures on cracking clay soils; and invasion of the Mitchell grass downs by the exotic weed, prickly acacia (*Acacia nilotica*). For species that survive burning by resprouting, such as melaleucas, intense fires can be used to keep most suckers below grass height. For species that are killed by fire, such as many Acacias, intense fires can be used to kill seedlings and saplings. Seasonal conditions obviously influence fire intensity. Grazing management is also important, because grazing must generally be excluded from areas to be burnt, in order to allow fuel-loads to build-up. Post-fire grazing management is also important, as good grass

cover helps to suppress regrowth of seedlings and saplings. In the monsoon tropics, very late in the dry season is the best time for achieving both intense fires and a high probability of subsequent grass growth, but it also carries the greatest wildfire risk. This is one of the reasons why the efficacy of using prescribed burning to control woody thickening declines as the woody plants become more established. Achieving the intensity of fire needed to knock back woody plants above about 2 metres tall poses an extreme wildfire risk. It may also become impossible once stands of woody plants become very dense, because they then suppress grass growth to such an extent that fuel loads never build up enough carry intense fires.

In temperate semi-arid and arid grasslands, wildfires are now infrequent and strategic burning is seldom practised. While experiments have demonstrated that most of the problem species are vulnerable to fire, achieving the appropriate timing and frequency is problematic. For example, some *Eremophila* species are resistant to annual spring burns but can be killed by two consecutive autumn burns. The probability of experiencing two consecutive good summer growing seasons is low, however, and the pastoral risks associated with burning grass reserves two years in a row are high. This may be why strategic burning is so seldom practised. Native tree and shrub species have now proliferated though much of semi-arid western New South Wales and southern Queensland, converting large areas of open grasslands and grassy woodlands into closed shrublands. A range of woody species is involved including mulga (*Acacia aneura*), white cypress pine (*Callitris glaucophylla*), budda (*Eremophila mitchellii*), turpentine (*E. sturtii*) and hopbush (*Dodonaea* spp.). Many previously open areas are now so densely wooded that fire is probably no longer viable as a control option.

In addition to modulating the balance between woody plants and grasses, fire regimes also influence the composition of grass species within pastures. In the Mitchell grasslands strategic burning may be practised to remove old pasture growth and promote vigour, and also to reduce the proportion of wiregrasses, which have a low forage value and seeds that contaminate wool. Both the frequency and timing of fires are important to achieving desired results. Too frequent fire may lead to increases in undesirable annual grasses as well as loss of valuable pasture reserves, but lack of fire increases the risk of destructive wildfire (especially in northwest Northern Territory and the Kimberley) and encroachment by woody plants. Where wildfire risk is high, as in the Kimberley region, Mitchell grasslands may be burnt every two to three years to combine hazard reduction and pasture rejuvenation. In the more extensive Mitchell grasslands of Queensland, where wildfire is less of a hazard, intervals between controlled burns may be of the order of 5–15 years. Fires must be carefully timed to achieve a shift in pasture composition. A moderately hot fire followed by two to three months of dry weather is needed to reduce the abundance of wiregrasses in Mitchell grass pastures. In Queensland the optimum time for this is July or August during a rising phase in the Southern Oscillation Index, when the probability of receiving sufficient summer rain for pasture production is high.

Strategic burning to manage the composition of pastures is also promoted in other tropical grasslands, but interactions are complex. For example, in tropical tall-grass pasture, less intense, early dry season fires favours kangaroo grass (*Themeda triandra*) whereas black speargrass (*Heteropogon contortus*) is promoted by high-intensity, late dry season fires. In eastern Queensland, however, annual spring burning coupled with deferred grazing is used to promote speargrass over poorer quality grasses.

The effects of this sort of strategic burning on biodiversity are largely unknown. In the absence of any specific information about the fire-related attributes of particular biota, fire regimes that promote variety and variability are generally considered the best-bet option for optimising biodiversity. Thus strategic burning for improved pasture composition is most likely to be beneficial for biodiversity if it also promotes a variety of habitats generated by different times between fires. In rarely burnt prime pastoral lands such as the Mitchell Grass Downs, a reintroduction of some degree of strategic burning is likely to benefit biodiversity by breaking up the large areas of long-unburnt habitats that currently predominate.

Fire management

Fire regimes that promote or allow woody thickening of natural grasslands have negative impacts on both biodiversity and production. The most immediate negative impact on pastoral production is reduced visibility and control of livestock during mustering operations. The longer term and potentially more serious impact is irreversible loss of pasture for livestock.

The impacts on biodiversity are more complex and less well understood, but are likely to relate to shifts in landscape pattern, habitat structure, and food availability. In the tropical savannas, for example, invasion of grasslands on Cape York Peninsula by woody plants, particularly tea-tree (*Melaleuca* spp., see also Section 3.3.2) has been implicated in the decline of threatened granivorous birds such as the golden-shouldered parrot, star finch, Gouldian finch, buff-breasted button-quail and black-faced woodswallow. Increased densities of woody plants has led to more successful predation by birds such as pied butcherbirds and loss of perennial grasses such as cockatoo grass (*Alloteropsis semialata*) which seed-eating birds rely on for food at critical periods of the year. However, woody thickening is not the only threat to declining granivorous birds. Continuity of food supply is also critical, and this is most likely to be maintained if there is a fine-scale mosaic of grassy areas burnt at different times throughout the year. This is because many granivorous birds eat mainly grass seeds that have fallen to the ground. Foraging is difficult in areas of dense grass, but far easier where patchy fires have removed grass bulk. However, intense, extensive late season fires not only remove the grass bulk but also destroy most of the fallen seed over areas far greater than the birds' home range. Thus the optimal fire regime for these species is one that controls woody thickening *and* retains a fine-grained mosaic of areas burnt at different times of year to ensure year-round food availability.

Spatially and temporally patchy fires are also thought to be important in arid and semi-arid tussock grasslands, for maintaining optimal habitat heterogeneity for the survival of endangered species such as the western hare-wallaby (*Lagochestes hirsutus*), bilby (*Macrotis lagotis*), and mulgara (*Dasycercus cristicauda*). In cases where optimal fire regimes for individual species are not known, a fire regime that provides variety and variability, preferably at a fine scale, is likely to provide for the greatest variety of species, by allowing individuals to pick and choose areas that meet their various requirements. Equally important, in a fine-scale patchy mosaic of habitats there will always be populations that can colonise areas as the vegetation changes through time between fires. As a general rule, large areas of monotonous habitat, whether created by extensive frequent wildfire or total fire exclusion, are likely to cater for fewer species and lower abundance of many of those that are there, than would the same areas if they contained a variety of habitats generated by fire.

Fire knowledge gaps

Despite a general appreciation that a variety of habitats generated by fire is likely to support more grassland biota than uniform tracts of unburnt or burnt habitats, there is a dearth of specific information about the actual fire regimes (fire interval, season of burn, size of burn patches, etc) that might best maintain biodiversity in different grassland types.

Though there is good general understanding that changed fire regimes are likely to have negative impacts on biodiversity, there is little specific information about how fire suppression has impacted on biodiversity in the arid and semi-arid tussock grasslands of the temperate rangelands.

Similarly, though it is possible to speculate about the impact of woody thickening on biodiversity, there is little specific information available. In most other grassland types, there has been no specific investigation of which flora and fauna (if any) have been most affected by woody thickening. The main exception is woody thickening of melaleuca grassy woodlands and associated grasslands on Cape York Peninsula, and its impacts on golden-shouldered parrots. Even here, however, there is poor understanding of how to actually implement fire regimes that would control woody thickening and maximise benefits for golden-shouldered parrots.

Invasion of grassland by exotic woody species such as prickly acacia (a weed of national significance) is likely to be to the detriment of native biota. However, there is so little documentation of actual impacts it is not possible to identify which biota may be most affected, nor what management response may be most effective in mitigating the most severe negative impacts.

Across the rangelands generally, Indigenous people have much to offer in terms of knowledge about using fire, but much of this knowledge is no longer used because people no longer live permanently on their country, and young people are not being educated about traditional knowledge.

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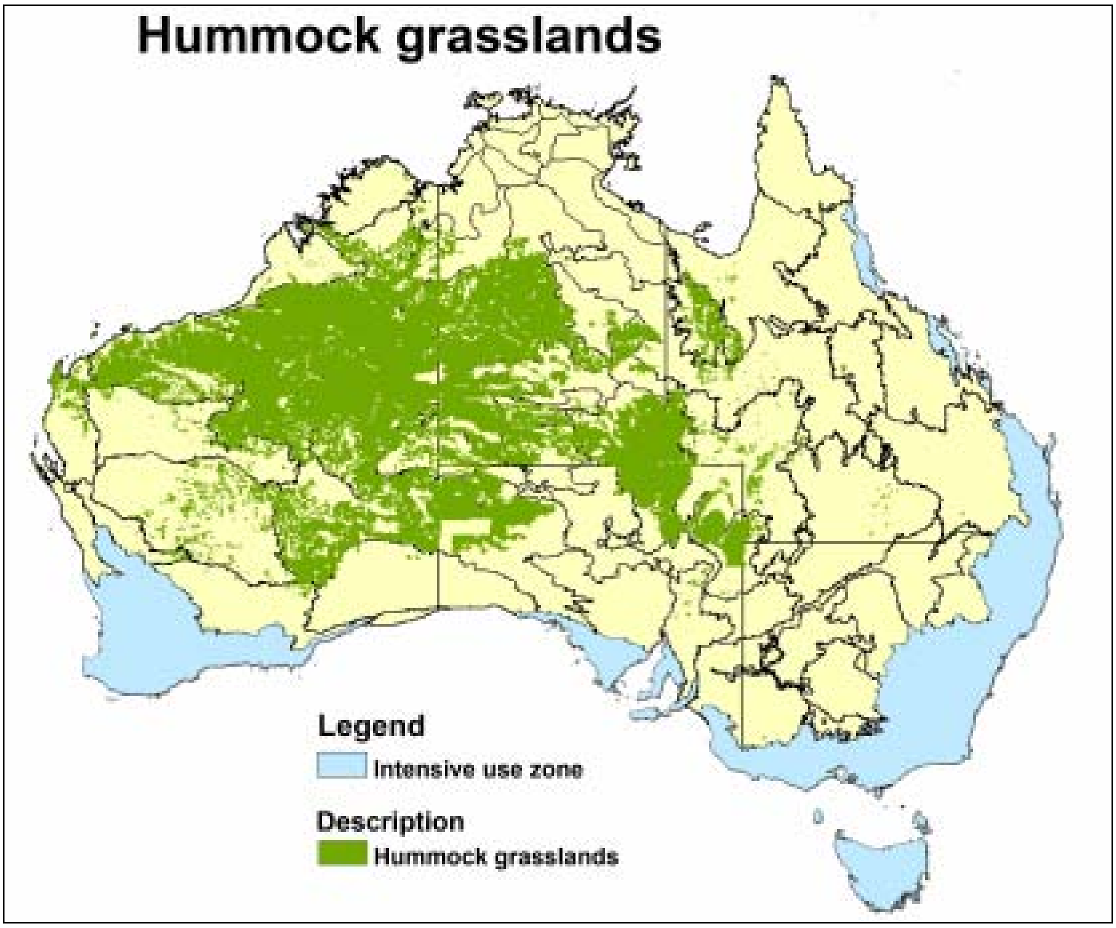

Figure 3.4 Distribution of hummock grasslands, NLWRA 2001 <www.nlwra.gov.au>

3.3.4. Hummock grasslands

Biophysical overview

Hummock, or spinifex, grasslands are characterised by a perennial grass understorey (*Triodia* spp.) with a variable shrubland overstorey, either *Acacia* or *Eucalyptus*, with both local and regional variability. Hummock grasslands occur within all three climate/fire regions of Australia, but they occur predominantly within the semi-arid/arid interior region. Their primary habitat is extensive flat landscapes of sandplains or sand dunes, including the southern mallee regions, but they also dominate the interior arid and tropical savanna mountain ranges and plateaus.

Fire ecology

Fire within hummock grasslands is linked to rainfall despite the fact that spinifex is a perennial fuel that persists during dry periods and is generally unaffected by pastoralism. Periods of high fire occurrence within hummock grasslands are associated with periods of two to three years of above-average rainfall that generate increased fuel loads over extensive areas even within pastoral lands.

Within all hummock grassland ecosystems there is a post-fire time lag in fuel recovery, which is primarily driven by rainfall. This time lag is also affected by individual spinifex species response. Spinifex is predominantly an obligate seeder, but in northern regions it is frequently a re-sprouter. Fuel load recovery and fire intervals are also affected by the presence of other understorey species. These are more common in the northern rainfall areas, or during periods of above-average rainfall.

Land tenure within spinifex landscapes is largely Aboriginal freehold and conservation reserve, however many pastoral and defence lands have considerable areas of spinifex. Fire is an important facet of land management within the hummock grasslands, both as a management tool and because wildfires impact on infrastructure, productivity and biodiversity. Fire also contributes to social

conflicts when uncontrolled fires, frequently from roadside ignitions, burn across land tenure boundaries and effect neighbouring resources and livelihoods.

Fires in hummock grasslands can occur throughout the year. The semi-arid/arid interior region is characterised by annual periods of high fire danger associated with hot, dry and windy summer conditions, but variable fuel loads associated with highly variable rainfall can moderate the risk. The most extensive wildfires are associated with periods of widespread above-average rainfall, which occur on 25–30 year cycles. Within central Australia these periods occurred in the early 1920s and 1950s, the mid 1970s, and during 2000–2002. Most large fires are associated with hot summer conditions in the interior and southern regions (October–February), or late in the dry season of the tropical savanna region (September–November).

Fire management

Throughout Australia, fire regimes have changed since European settlement and the associated ecological impact is a major issue within spinifex landscapes. The rate and nature of the change has been quite variable in both space and time across the extensive area of spinifex. The change has been associated with both shifting populations and changed land use and tenure. Although it is difficult to measure the change, there has been a general shift from numerous small fires to less frequent large intense fires, similar to changes in tropical savanna ecosystems. This leads to homogenisation of age stands of spinifex over very large areas, and the damaging effects of large wildfires when they do occur. In some areas, fire exclusion, usually associated with cattle grazing on pastoral lands, has nearly eliminated fire from portions of the spinifex landscapes. Overall these changed fire regimes have been linked to the decline of many species of medium-sized mammals and some reptiles in the arid lands, in association with other factors such as feral animals.

The impact on vegetation is also of concern. Within the extensive areas of spinifex there are many diverse fine-grain ecosystem components that include fire-sensitive vegetation. Examples include saline vegetation communities associated with palaeodrainage lines, salt lakes and soaks; *Callitris* and heath communities within the central ranges, and *Ficus* species on isolated rocky outcrops. The persistence of these areas is threatened by the current fire regime. Trans-boundary issues of fire transgressing from the spinifex into neighbouring *Acacia* shrublands (mulga) landscapes is also a major concern. The potential impact is to reduce the real extent of the mulga lands as well as their biodiversity.

Although most spinifex areas are not considered productive land for cattle grazing, they are a dominant part of many pastoral leases. In northern areas, spinifex is burnt to provide short term post-fire response of palatable species, predominantly grasses, or to reduce fire risk to adjacent more valuable pastoral lands. There are sustainability issues associated with high fire frequency in these areas, that may contribute to decline of woody species diversity and impact on fine-grain vegetation components. Fire in the central and southern regions is less frequently used in pasture management but fire spread from spinifex areas into adjacent pasture lands is a management issue and needs to be better addressed as a landscape risk issue. This also applies to the large areas of spinifex in the rough and relatively inaccessible landscape of the desert and sub-tropical mountain ranges. Topography has a significant effort on the patterning and intensity of fires, and the associated management issues of suppression. Many pockets of high biodiversity persist within the ranges but coodinating and implementing fire management programs with numerous land managers in these areas has had minimal success.

Within the extensive areas of spinifex under Aboriginal freehold tenure, empowerment of Aboriginal people to return to their country for burning and other landscape management activities is a major challenge. The opportunity for many individuals to return to their lands has been improved during the past 20 years through the outstation movement and the purchase of many pastoral leases. However implementation of land management programs is frequently affected by health and survival issues within Aboriginal communities. There is also an ongoing loss of traditional knowledge linked to social issues within communities and a shift of priorities within younger generations.

Fire knowledge gaps

Research on fire and landscape management within hummock grasslands has addressed fire behaviour; mapping fire mosaics; dynamics of spinifex and mulga communities, and responses of some species of vegetation and fauna. Research has been undertaken predominantly on Aboriginal and conservation lands, and there is a need for more work on pastoral lands. There is still a need to improve our

knowledge of species and community responses to fire, especially within the context of a highly variable climate in the semi-arid to arid environment. Species of the hummock grasslands in the NT are included in the NT fire species attribute database (see also Appendix 2). However, regional variations in both species composition and their responses in areas outside the NT need to be captured.

Following extensive fires in central Australia during 2000 to 2002, it was realised that more effective fire management required regional plans across a collective of land tenures and land managers. The plans accepted differing perspectives on fire but included a commitment of participation. The challenge remains to maintain the commitments during seasons of reduced fire risk and to implement the programs. The success of a few regional plans will help extend the program to other areas.

Mapping resources are required for effective management plan development and implementation. Specific hummock grassland species distribution/dominance maps are needed. General information is known for the distribution of each individual *Triodia* species, and point sampling can indicate local occurrence and dominance for many locations. However our lack of understanding of species site preferences and past patterns of species evolution and expansion restricts our ability to generate an accurate species map across the extensive area of hummock grasslands. This information is significant to fuel load recovery models that are based on fire response by species (i.e. recovery of the obligate re-seeder species is slower than re-sprouting spinifex species within similar environments).

The challenge of implementing fire management programs within the vast areas of Aboriginal land is another challenge. Aboriginal communities are interested in employment opportunities and land management ranger programs with fire management as a component are beginning to succeed. Their success is currently restricted to regions where mining activities provide funding opportunities. Maintaining and expanding these programs to other areas is a future challenge.

The basis for any successful fire management program is an accurate fire history database. Continental fire history databases derived from coarse-resolution satellite images provide a good perspective of fire regimes, but do not have the spatial accuracy for many fire management programs addressing biodiversity issues. Methods have been developed for mapping fires from moderate and high-resolution satellite images. The challenges are to commit time and resources to process satellite images and to incorporate fire history information into management programs.

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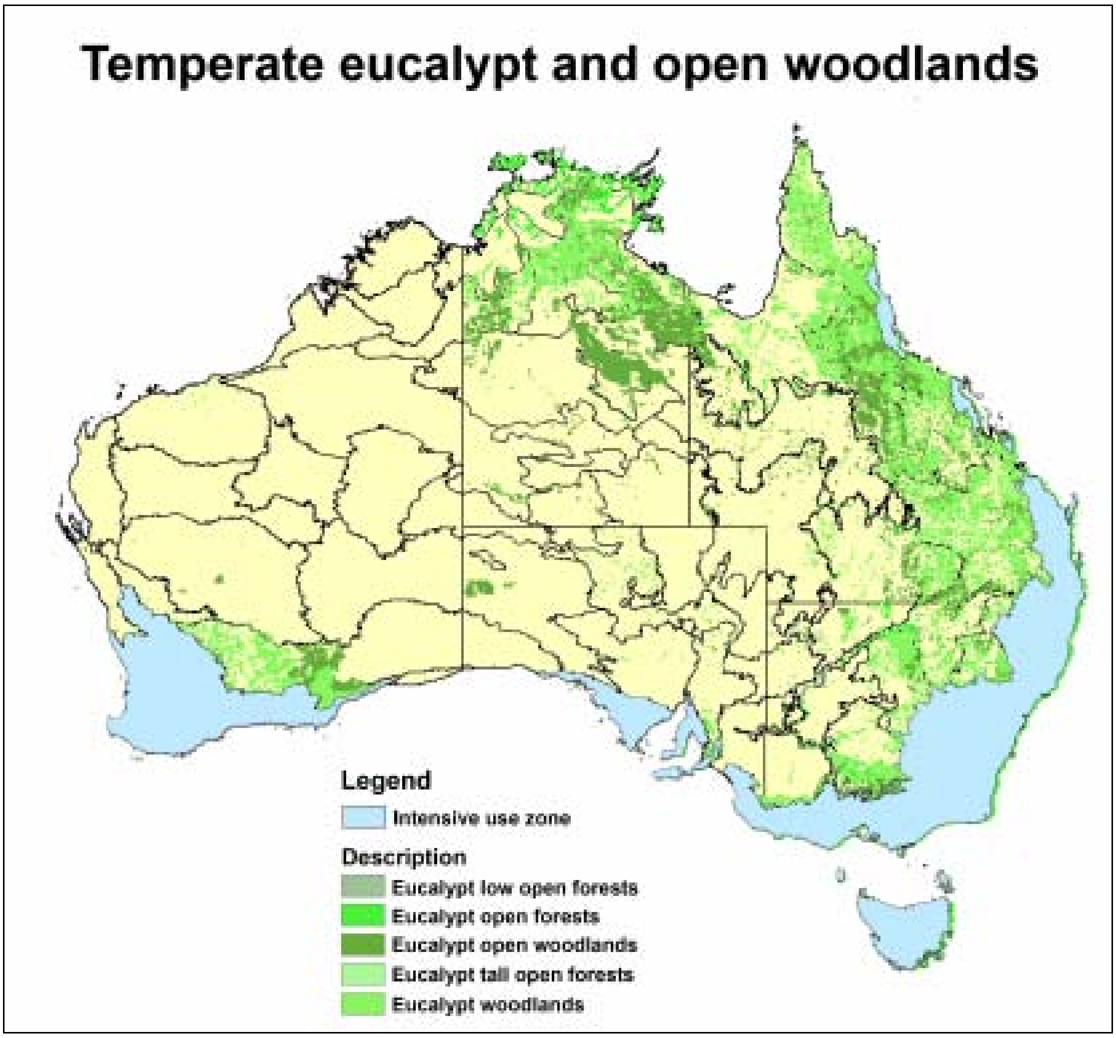

Figure 3.5 Distribution of eucalypt and open woodlands, NLWRA 2001 <www.nlwra.gov.au>
Note that this section refers to these communities where they occur in temperate latitudes.

3.3.5. Temperate eucalypt and open woodlands

Biophysical overview

Temperate woodlands occupy a considerable area of the rangelands in south-eastern and western Australia. Such woodlands in the semi-arid regions of south-eastern Australia are dominated by a variety of *Eucalyptus* and *Corymbia* species, with *Callitris, Casuarina, Allocasuarina, Acacia* or *Brachychiton* species as co-dominant or subdominant trees. Woodlands dominated by *Casuarina* and *Heterodendron* with eucalypts sparse or absent may also be found in the drier parts of these regions. Woodlands in the semi-arid regions of south-western Australia are dominated by various *Eucalyptus* species with *Acacia, Casuarina* and *Agonis* species present in some communities as small trees. Areas dominated by *Casuarina* exist in the drier eastern margins. Understoreys are highly variable and may contain a diverse range of shrubs and small trees, grasses and forbs, many of which are ephemeral. Exotic plant species are prominent in these woodlands, particularly in the ground layer of the vegetation.

Species composition and structure of the overstorey and understorey is determined by soil types, landscape position (ridges versus drainage lines) and by fire and grazing regimes. These woodlands lie adjacent to and may be intermingled with a variety of other communities. With increasing rainfall, these communities may grade into open forests or even heaths (in situations with poor soils) whereas with decreasing rainfall they may grade into chenopod shrublands, mallee shrublands and various grasslands depending on soil types and other landscape factors.

Fire ecology

The dry, temperate woodlands in many regions have been depleted and fragmented to varying degrees by pastoral and agriculture usage. Over-grazing has resulting from the combined effects of domestic, feral and native animals, has resulted in significant changes in composition including the loss of perennial grasses and replacement by ephemeral grasses and herbs and in some instances (e.g. lighter textured soils) a dense layer of shrubs and trees such as *Callitris* and mulga (*Acacia aneura*). The retention of perennial cover, particularly by grasses, is a major issue in these woodlands. In turn, changes in the fire regime, particularly a decline in fire incidence due to an absence or marked reduction of herbaceous fuel, is a direct consequence of over-grazing. The replacement of perennial grasses by ephemeral grasses and herbs, in particular, may have strengthened the dependence of the fire cycle on sporadic climatic events (see below).

Woodland plants exhibit a variety of ways of coping with and regenerating from fire. Eucalypts and other tree species such as *Casuarina* and *Brachychiton* typically resprout after fire. Individuals of other species such as some acacias and *Callitris* may be killed when fires fully scorch the crowns. Some shrub species resprout after fire while others don't. Fire may promote seedling regeneration in these communities by opening up space and increasing other resources but the exact role of fire in recruitment is still unclear in many cases.

Post-fire grazing can have a significant impact on regeneration of both herbaceous and woody plant species—particularly those species that recover from fire through seedling germination and establishment. Inappropriate stocking (either too low or high depending on local species and conditions) can unfavourably alter the long-term composition of these woodlands, in terms of both pastoral productivity and biodiversity conservation.

Clearing for cropping or to increase herbage has exacerbated many of the changes that have occurred in these woodlands in the pastoral era. Local management must therefore consider the condition (changes in the shrub/herb/grass mix) and fragmentation of communities, as well as interactions between fire and grazing. The existence of exotic plants in many of these woodlands adds further complexity. In fragmented woodland vegetation, fire may hasten the invasion of exotic species, particularly invasive grasses, and there may be a direct inhibitory effect of exotics on the recovery of native species after fire.

The dry temperate woodlands occur in both winter and summer rainfall dominated climatic regions in both the east and west. Woody plants in the overstorey and understorey may produce litter fuels that accumulate in a predictable manner over time, but due to the open nature of the tree canopy, such litter fuels may be discontinuous in space. Such fuels are complemented by both perennial and ephemeral herbage that may fluctuate in both mass and spatial continuity in response to rainfall and grazing. The ephemeral component of surface fuels often provides the critical level of spatial continuity that is needed for fires to spread effectively over significant areas. Hence extensive livestock grazing has the capacity to significantly affect the incidence and size of fires and therefore the interval and intensity of fires experienced at any particular point within these woodlands. The presence of exotic herbs and grasses may also alter the quantity and continuity of fuel.

Fire management

As a result of the above factors, fire regimes may be largely driven by fluctuations in rainfall, with major fire events following successive years of above-average rainfall (e.g. 1974/75 and 1984/85 in western NSW) affecting, at least, those woodlands that have not been heavily fragmented. Lightning is a predominant source of fire in these woodlands. As noted, the size and pattern of fires in contemporary landscapes may be strongly affected by fragmentation of vegetation and, the state of herbage fuels as determined by past and contemporary livestock grazing. Such factors have resulted in a relatively low incidence of fire across many regions containing temperate semi-arid woodlands, but definitive data on fire area, recurrence and intensity is generally lacking for the bulk of these woodlands. As a consequence, a concerted effort may be needed to document recent fire history in many regions containing these woodlands.

Fire knowledge gaps

In terms of biodiversity, the current, relatively low rate of fire recurrence may be significant in terms of limiting recruitment processes for many plants, particularly overstorey woody species. Conversely such low rates of fire recurrence may perpetuate shrub populations in areas that were formerly open and

grassy. The reintroduction of fire may be considered as part of restoration processes directed at components of the flora (e.g. perennial grasses and other herbs) that have declined in response to overgrazing. The success of any use of fire in this context may be dependent on the relative status of seedbanks of native shrubs, herbs and grasses, along with those of exotic species. If for example, seedbanks of grasses have declined or are missing, while shrub seedbanks are high, active use of fire may be unsuccessful in restoring grasses and reducing shrub densities. Equally, in instances where fire has been absent for long periods (i.e. decades) and there is evidence of decline of components of vegetation that are dependent on fire for recruitment, active use of fire may be required to ensure the maintenance of these elements. Such may be the case in highly fragmented woodlands.

The response of exotic plant species to prescribed fire may need to be taken into account when planning prescribed fires, given evidence that fire may promote exotic herbs and grasses in some instances, and that this may have detrimental effects on the responses of native plant species.

Given that significant areas of these woodlands have experienced relatively little fire and concurrent evidence for decline in this manner exists, there is much scope for the targeted use of prescribed fire for the conservation of biodiversity in temperate semi-arid woodlands. Local use of fire in this manner needs to predicated on available evidence derived from recent fire history, an understanding of the life histories and population characteristics of the species concerned, or if unavailable, appropriate biological indicators dealing with the condition of vegetation (e.g. see above). There is still much to learn about the biology of many woodland species in this regard. New information will further aid management.

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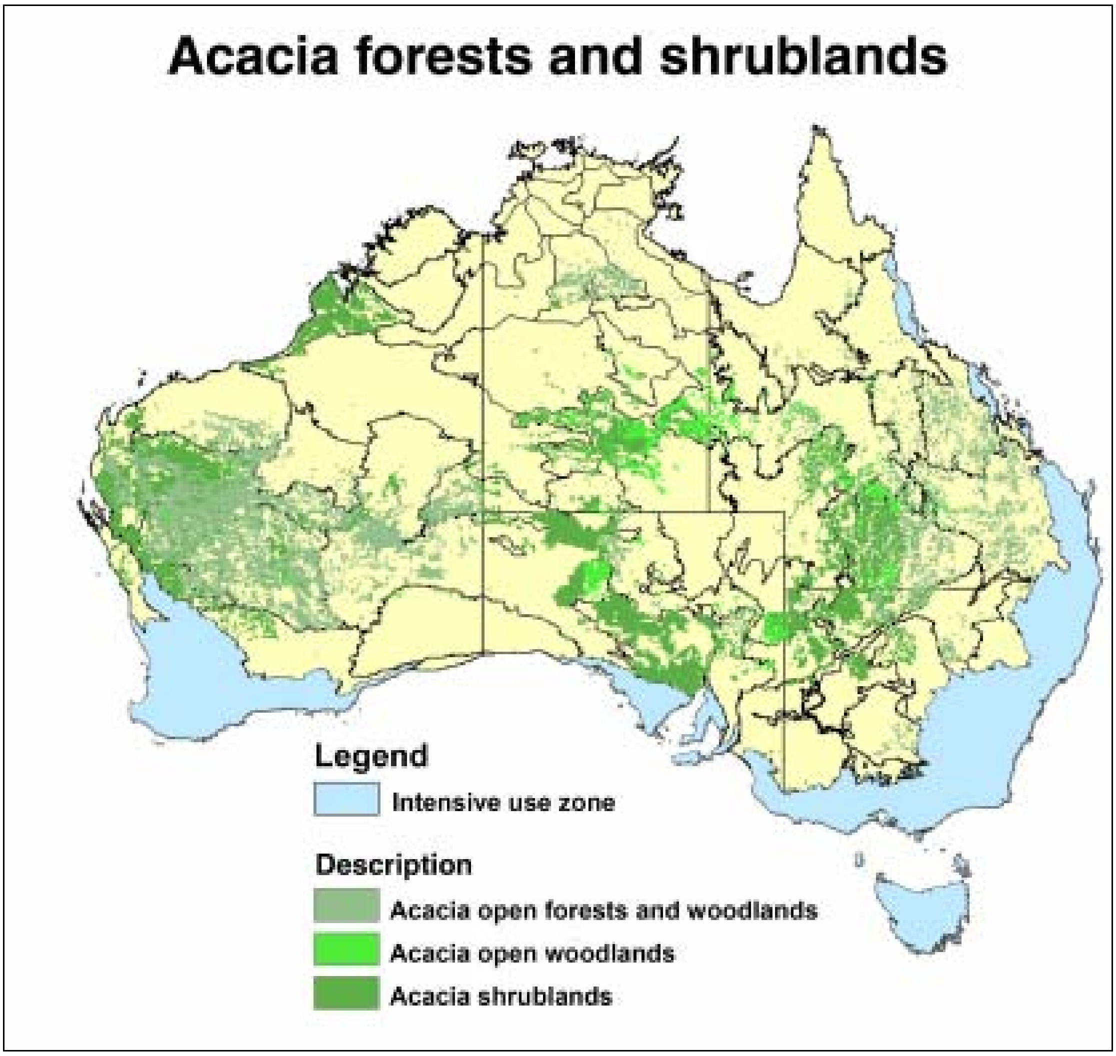

Figure 3.6 Distribution of acacia forests, woodlands, open woodlands and shrublands, NLWRA 2001 <www.nlwra.gov.au>

3.3.6. Acacia forests, woodlands, open woodlands and shrublands

Biophysical overview

Acacia-dominated vegetation types occur as tracts, or more commonly as patches within broad expanses of other vegetation types throughout the Australian rangeland region, but particularly across the mid-latitudes of arid to semi-arid (<600 mm rainfall p.a.) western, central, and sub-coastal eastern Australia (Hodgkinson 2002). *Acacia*-dominated vegetation types describe a variety of structural formations (forests, woodlands, open woodlands, shrublands; Fig. 3.6, NLWRA 2001) and a broad array of floristic associations (Beadle 1981; Johnson and Burrows 1994). As well, acacias are common floristic components of most other major Australian vegetation types. The Australian Natural Resources Atlas describes 17.3% of contemporary Australian vegetation as being dominated by *Acacia* (forests and woodlands 7.3%, open woodlands 1.5%, shrublands 8.5%) <http://audit.deh.gov.au/ANRA/atlas_home.cfm>.

Extensive *Acacia*-dominated vegetation types, typically dominated by one *Acacia* species, include Mulga (*Acacia aneura*), Brigalow (*Acacia harpophylla*), Lancewood (*Acacia shirleyi*), Bendee (*Acacia catenulata*), Myall (*Acacia papyrocarpa*), Gidgee (*Acacia cambagei*). Of these, Mulga communities are by far the most extensive, occurring either as pure stands or, more typically, intermixed with hummock grasslands or other herbaceous types, over 20% of the continent (Johnson and Burrows 1994). Mulga associations extend in a discontinuous belt from near the Western Australian coast, across the southern edge of the central deserts, to western NSW and southwest QLD, with another substantial occurrence in the north of the central arid area in the NT. The distributions of

each of the above taxa (including the many varieties of Mulga), and all other Australian *Acacia* species, can be found in the on-line publication of the Flora of Australia.

<http://www.deh.gov.au/biodiversity/abrs/publications/flora-of-australia>

Fire ecology

Given the diverse array of floristic and structural assemblages that constitute Australia's *Acacia*-dominated vegetation, it is not possible to make generalisations about their fire ecology. For some dominant acacias, especially Mulga, a considerable amount is documented about the species' response(s) to fire. Thus, Mulga is recorded as being a potentially long-lived (>200 years), mostly obligate seeder species, requiring from between 5–15 years after a fire has killed adult stems before the new crop (or cohort) of seedlings has developed to maturity and begun to set viable seed of their own. However, in some situations Mulga is observed to resprout from basal suckers. Fire promotes germination of soil-held seed banks; however, success of Mulga germination and regeneration is dependent on adequate soil moisture. Adequate soil moisture is also important for flowering and fruiting. For central Australia at least, Jann Williams (2002) provides an excellent overview of, and pertinent references to, the fire ecology of Mulga communities, including interactions with flammable hummock grasslands.

Like Mulga, other dominant acacias such as Lancewood, Bendee, Gidgee (and many smaller shrub-sized taxa) are obligate seeders; others such as Brigalow are well known for being able to regenerate from root suckers. In general, however, information concerning the ability or otherwise of different acacias to regenerate after stems are killed by fire either vegetatively (i.e. from basal stem sprouts, or from root suckers), or from seed alone, is not readily available. For example, individual *Acacia* species descriptions in the Flora of Australia do not typically provide any information concerning fire response.

Given that the great majority of *Acacia*-dominated vegetation occurs under semi-arid and arid climatic conditions, the interval between fires is strongly dependent on the build up of grassy or herbaceous fuels which are, in turn, dependent on cumulative rainfall since the last fire. Thus, whereas fire intervals under arid climatic conditions can be as much as 30 or more years under consistently low rainfall conditions, in periods of high rainfall such as has occurred in the mid-1970s and, more recently, the turn of the new millennium, repeat fires have been observed to occur within a few years. In northern Australia, with highly reliable annual wet seasons, grassy fuel accumulation on the margins of *Acacia*-dominated assemblages is sufficient to support relatively intense fires every 2–3 years. The continuing spread of introduced buffel grass pastures in Queensland in situations adjoining acacia scrubs also provides for significantly greater, and more continuous fuels than were present in the past. As a result, fires are more frequent and there is a tendency for acacia-dominated shrubland to be replaced by grassland. This loss of structural diversity is linked with reduced species diversity at a local scale.

It follows that, for management purposes, whether for using fire to control shrubby acacia regrowth in a pastoral management context, or for implementing conservation-focused fire management regimes for maintaining viable acacia populations / biodiversity, a first requirement is to assemble such pertinent information as available, either from the formal scientific literature, or anecdotal sources. Key issues are: (1) does the particular species resprout or sucker after fires of low-moderate, or even high intensity; or (2) if not, how long does the new cohort of seedlings take to attain sexual maturity and set viable seed; and (3) what fire regime is appropriate for ongoing management purposes. Given that much required information is not currently readily available, it further emphasises the pressing need for developing regionally-relevant, species-specific, fire-response databases

Fire management

Fire impacts on associated flora and fauna are mostly equivocal and further data are required. However, it stands to reason that in situations where the extent of *Acacia*-dominated assemblages are being substantially reduced or more fragmented by contemporary fire regimes (and clearing), it follows that there would be significant impacts on associated or dependent species. For example, a study conducted in Mulga vegetation in the Pilbara region of W.A. reported that many fauna and flora species were reputedly restricted to that vegetation type. Consequently any reduction in their extent, or modification of their structure/composition, could significantly impinge on the conservation status of such ecosystems (van Leeuwin et al. 1995).

Clearing and degradation due to pastoral impacts and contemporary fire regimes are affecting substantial areas of *Acacia*-dominated assemblages. Forests and woodlands, especially Brigalow assemblages in eastern Australia, are most affected by clearing and other pastoral improvement practices. The NLWRA (2001) reports that 15% of the pre-European extent of *Acacia*-dominated forest and woodland, and 3% of open woodland and shrubland assemblages, have been cleared. While contemporary fire regimes are implicated in recent contractions in the range of Mulga in some parts of central and western Australia (Williams 2002), actual quantitative data are sparse. Indeed, reports of increases in *Acacia* shrub density in other parts of the rangelands (e.g. western Queensland), highlights the need for more detailed regional assessments.

Boundary issues

As with various other more restricted vegetation types in the rangelands (e.g. patches of monsoon rainforest, *Callitris* groves), the boundaries of *Acacia*-dominated stands are dynamically dependent on the severity, or otherwise, of local fire regimes. Structurally intact *Acacia* stands typically are associated with very low fuel loads, comprising mostly sparse leaf litter and scattered herbs and grasses. Where the canopy is opened up, for example by death of canopy trees caused by intense fire burning onto *Acacia* patch margins, more flammable grassy fuels, and the potential for further fire incursions, are promoted. Examples of such a fire cycle operating in Mulga communities in central Australia are given in Latz (1995), Allan and Southgate (2002), Williams (2002).

Land use / tenure

In the eastern States, *Acacia*-dominated vegetation occurs mostly on leasehold land used primarily for pastoral production. In Queensland, substantial areas of *Acacia*-dominated forest and woodland occurs on freehold tenure. In SA and NT significant areas of *Acacia*-dominated vegetation occur also on Aboriginal lands and, in WA, on Vacant Crown Lands. Just over 3% of *Acacia*-dominated vegetation occurs in protected areas (NLWRA 2001).

Fire knowledge gaps

There is a critical need for documentation of fire responses of the dominant Acacia species.

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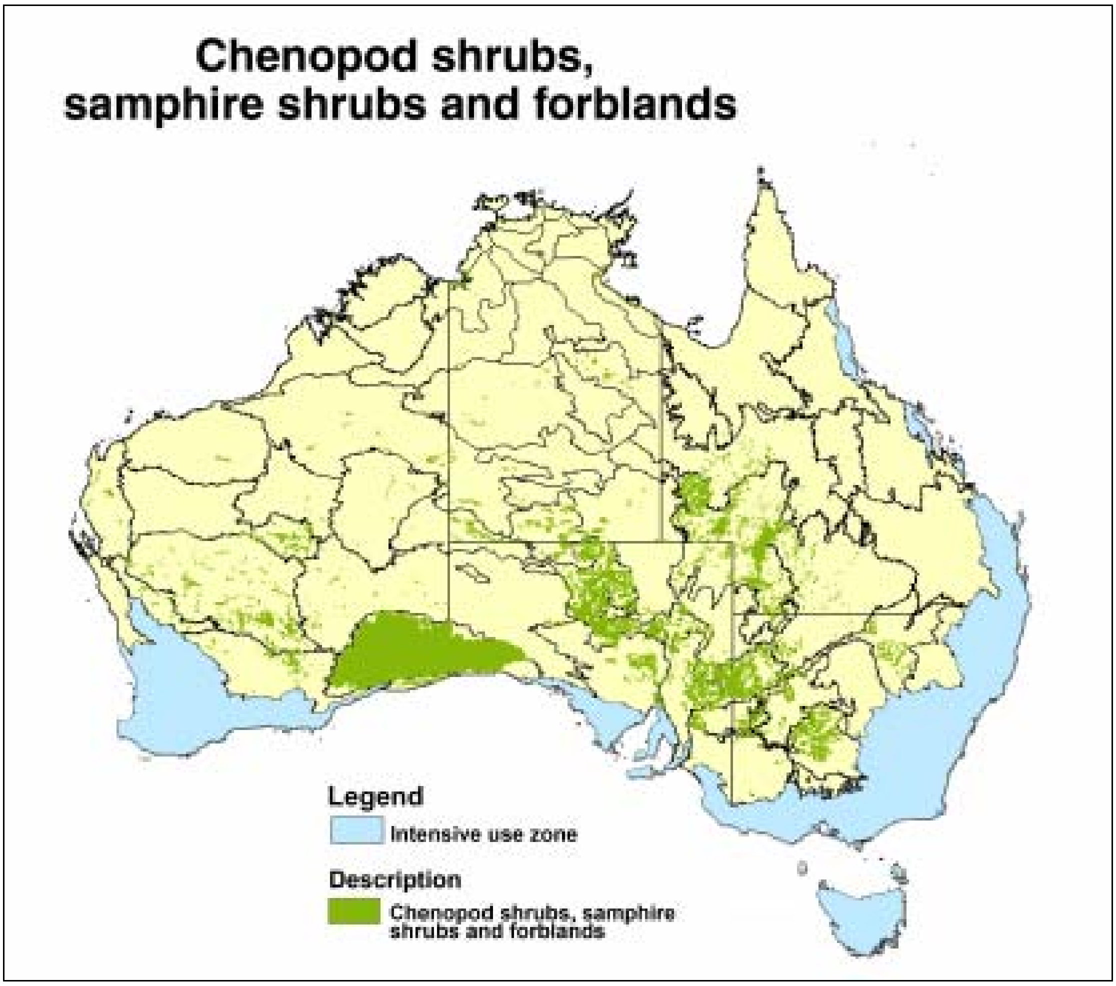

Figure 3.7 Distribution of chenopod shrubs, samphires and forblands, NLWRA 2001 <www.nlwra.gov.au>

3.3.7. Chenopod shrubs, samphire, forblands

Biophysical overview

Chenopod shrublands are extensive throughout the southern Australia in both the semi-arid and arid zones, where winter rainfall is reliable. They typically occur on soils of heavy texture and saline status in a variety of lowland landscape types (e.g. plains and drainage channels). Such soils generally prohibit the establishment of trees and other woody plant species. Species of *Atriplex, Maireana, Chenopodium* are dominant shrubs in these communities with species of *Sclerolaena* present as small shrubs or sub-shrubs in some communities. Grasses (perennial and ephemeral) and other herbs occur as a ground layer (and fuel source) in these communities. Chenopod shrublands may lie adjacent to or be intermingled with a variety of temperate woodlands and mallee shrublands.

Fire ecology

Chenopod shrublands have a long history of pastoral management. Both herbage and chenopod shrub foliage are palatable to stock. Overgrazing can lead to the loss of shrubs and conversion of these shrublands to grasslands. Extensive areas have been degraded in this manner

Chenopod shrub species readily die when exposed to fire, though the foliage is essentially non-flammable due to the high salt content and succulent nature of the leaves. These species tend to lack storages of seeds hence a single fire can cause depletion or elimination of populations. Communities dominated by these shrubs will only burn if there is sufficient herb/grass biomass and continuity and, as with many other arid or semi-arid communities, such conditions follow periods of above-average rain. For example, large areas of chenopod shrublands were burnt in 1975/76 following a sustained period of exceptional rainfall. The flammability of these shrublands is enhanced by the degradation of

the shrub layer allowing space for expansion of grasses and herbs, and thus fuel, following wet years. Fire may therefore hasten the elimination of shrubs initiated by over-grazing.

Fire management

In some respects, fire management of chenopod shrublands is relatively simple. Fire should continue to be excluded from these shrublands because the dominant species are unable to regenerate after burning. Under most conditions these shrublands are not likely to burn and fire exclusion does not require active intervention. Under exceptional conditions, following a sustained period of above-average rainfall, active intervention may be required to pre-empt burning. This may involve treatment of adjacent, more flammable plant communities and consideration of the adequacy of access to areas where suppression may be used to prevent the entry of fires into chenopod shrublands. A continuing priority will be the careful management of grazing and thus prevention of the degradation of the dominant shrub layer. This is predicated on the assumption that the best way of managing fire in these communities is to retain the non-flammable dominant shrub populations. In the wider landscape, retention of these non-flammable shrublands may also have significant effects on the fire regimes experienced in other communities. Degradation of chenopod shrublands may, for example, increase the potential for large, landscape-scale fires.

Fire knowledge gaps

As with many other temperate semi-arid communities, the recent fire history in these shrublands is uncertain. Where possible, clarification of areas affected by recent fires may be important. Identification of the degree and extent of degradation of chenopod shrublands through over-grazing may assist in pin-pointing areas that could be vulnerable in the future to the encroachment of fire. These strands of information will be useful in future planning.

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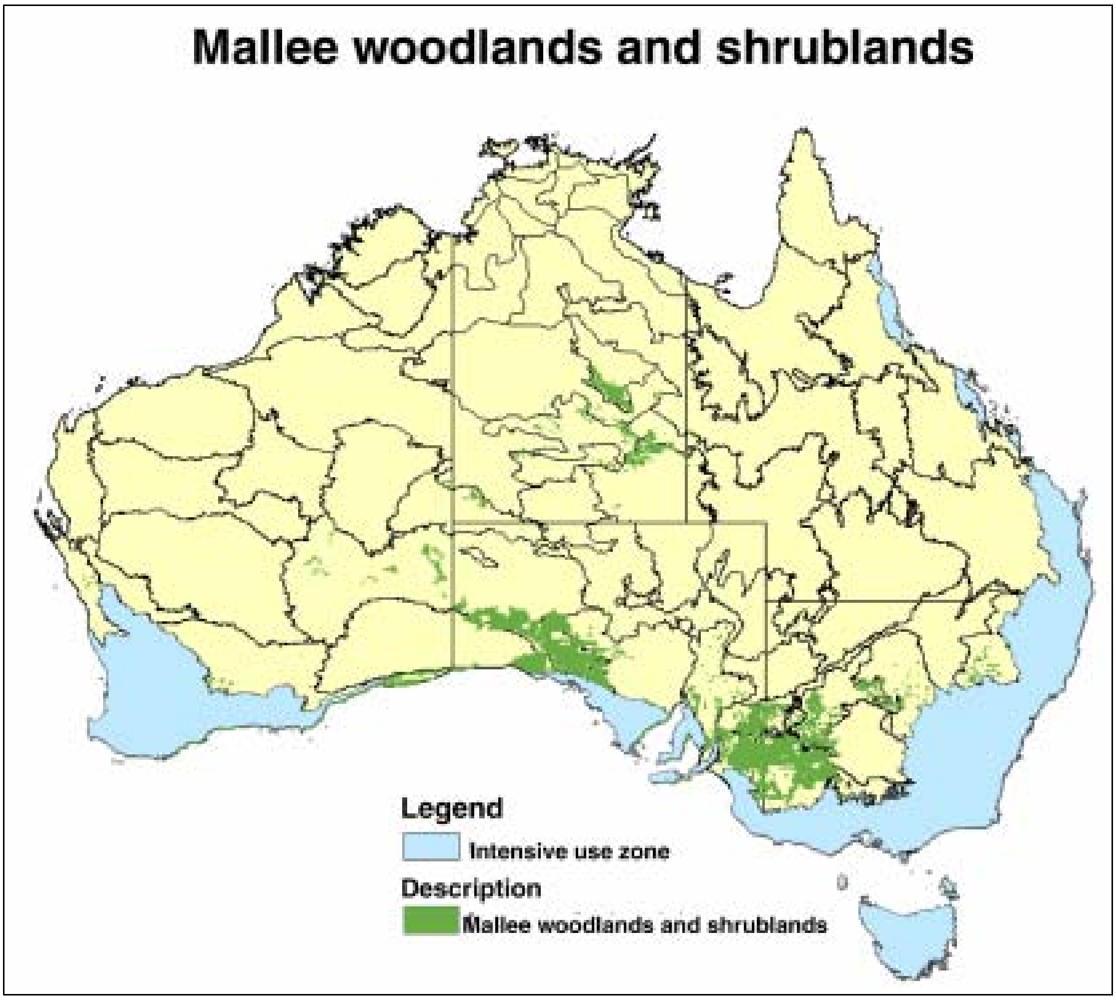

Figure 3.8 Distribution of mallee vegetation, NLWRA 2001 <www.nlwra.gov.au>

3.3.8. Mallee

Biophysical overview

Shrublands dominated by multi-stemmed eucalypts (mallees) occur on coarse textured soils (e.g. dune and sandsheet landforms) throughout the semi-arid, mediterranean-climate type regions of southern Australia. Species of *Callitris* may occur as co-dominants or emergent trees in mallee shrublands, while understories may vary (e.g. chenopod/ephemeral grass mixture, dense shrubs or a prominent layer of perennial hummock grasses—*Triodia* spp.). Mallee shrublands may be found adjacent to or interspersed with other shrublands (e.g. chenopod dominated) or woodlands, usually located on heavier textured soils and differing landforms. On sandy soils, mallee may also grade into heathlands where rainfall is higher.

Because mallee generally occupies less fertile and hence less productive landscapes it has traditionally been stocked by domestic herbivores at low levels. Often mallee is used as a drought reserve in pastoral enterprises to complement more productive woodlands and chenopod shrublands. Mallee landscapes have however been extensively cleared for cereal cropping. This may have had far reaching effects on regional fire regimes and has created isolated remnants of mallee vegetation.

Fire ecology

Most mallee plant communities, with the exception of those with a chenopod understorey, are flammable and may experience regular fire. In particular, relatively intense, fast moving crown fires can occur in mallee with a dense ground layer of *Triodia*. A shrub layer may enhance the propagation of fires into eucalypt crowns. Spotting is a feature of mallee fires – possibly due to the loose strands of bark and other suspended litter that accumulate at the base of individual mallee plants. The litter

produced by overstorey eucalypts exhibits a regular temporal pattern of accumulation. Spatially, eucalypt litter is discontinuous, being typically confined within the margins of individual canopies. Given the open nature of these shrublands much space exists between individual canopies. The space between canopies can be bare or filled with perennial or ephemeral understorey plants, which can provide continuity of surface fuel. *Triodia* species on deep sandy soils provide a conspicuous and relatively flammable perennial fuel type. Ephemeral herbs and grasses (e.g. *Stipa* spp.) are also a prominent source of fuel, particularly following a succession of wet years.

Mallee plant communities show remarkable resilience after fire. A large proportion of perennial species vigorously resprout following fire, including overstorey eucalypts, shrubs (e.g. *Eremophila*, *Grevillea*, *Melaleauca* spp.) and grasses (e.g. *Triodia* spp.). It is notable however, that even the seemingly inexhaustible resprouting capacity of mallee eucalypts can fail under annual or biennial burning – particularly in autumn. Many herbs, *Triodia* in some instances, some understorey shrubs (e.g. *Acacia*, *Senna* spp.) and the co-dominant *Callitris* species lack resprouting ability. Most perennial plants in mallee, whether woody or herbaceous, appear to depend substantially on fire for germination and establishment of seedlings and recruitment of juveniles. Individuals of these species may die when burnt (depending on fire intensity), hence post-fire regeneration is dependent on the presence of seed storages and favourable condition for germination and establishment post-fire. The rates of post-fire growth and maturation of these plant species are an important consideration in fire management of mallee vegetation. At least 5–10 years may be required after fire for populations of these species to reach maturity. Post-fire grazing by native herbivores, domestic stock or other exotic species may adversely affect regeneration rates and population densities.

Mallee has a rich reptilian fauna that responds to fire. In particular, the density and composition of the grass/herbage layer may affect the richness and abundance of species. Reductions in grass/herbage cover may negatively affect reptilean diversity. A number of birds require some areas of old mallee, i.e. more than 30-50 years post-fire age, such as Major Mitchell's cockatoo (*Cacatua leadbeateri*), whilst others prefer, or require, mallee less than 10 years old, such as the chestnut quail thrush *(Cinclosoma castanotus*), shy heathwren (*Hylacola cauta*) and scarlet-chested parrot (*Neophema splendida*). Yet other species utilise adjacent old (>30 years, and preferably > 60 years) and young mallee (<10 years, which may contain greater food resources), such as the mallee fowl *Leipoa ocellata* (Benshemesh 1990). Areas of long-unburnt mallee (i.e. intervals longer than 40 years) may be required to support such species.

Fire management

Mallee is typically burnt on a 10–20 year cycle by relatively large fires. This reflects the influence of both rates of ignition and fuel accumulation. A continuous layer of surface fuels is only present over large areas of mallee after extended periods of above average rain. Ignition from lightning can trigger large fires following curing of the ephemeral herbs and grasses that result from such rain. This coincidence of rainfall and dry lightning storms seems to occur on a decadal to bi-decadal cycle in many mallee regions, though ignitions by lightning in such circumstances are not inevitable. Major fire seasons in the Murray mallee region (Victoria, NSW, South Australia) and the central NSW mallee have for example occurred in 1957, 1975, 1985 and 2002.

Currently anthropogenic ignition rates (planned and unplanned) are relatively low, reflecting low population densities in these areas. Strategic prescribed burning, particularly in conservation reserves in the south-east, is commonly used to assist in wildfire suppression and habitat management. Some prescribed burning has also been employed to enhance pastoral values in NSW. A network of fire trails was established throughout the major remaining tracts of NSW mallee following the 1975 fires to facilitate fire suppression and prescribed burning. In highly fragmented mallee landscapes, remnant vegetation may experience little or no fire.

Fire knowledge gaps

A number of major challenges exist in managing the mallee. There is a need to consolidate information about prevailing fire regimes, particularly in the west. This would provide a more informed basis for management. Knowledge of plant attributes in relation to fire is relatively good – a similar level of knowledge is needed for animals. In particular much more information is required to understand how groups such as insects and reptiles respond to differing fire regimes. The requirements of avifauna that appear to have some linkage to long unburnt mallee require further investigation. A key issue that

requires further research is the relative dependence of plant recruitment on fire. Such information is needed to underpin the active use of fire for ecological purposes in long unburnt mallee.

In practical terms, there is wide scope for maintenance and expansion of strategic prescribed burning programs to serve a variety of objectives. The need for prescribed burning for biodiversity conservation purposes may become more pressing in remnant vegetation, giving that much clearing has occurred in the last 40 years. Unburnt remnants in these landscapes may be entering a state where residual seedbanks are in decline, threatening species composition in the longer term. Fire management in mallee remnants may be complicated by the presence of exotic species which may exploit post fire conditions so due care and monitoring is needed. Care is needed also in managing effects of post-fire grazing (by native domestic and exotic species) on the recovery and recruitment of perennial plant species. Ongoing rabbit and goat control programs may be critical.

In the larger expanses of mallee, as in many other vegetation types, the optimal level of fire management intervention remains unresolved. The development of monitoring programs in conjunction with further research on species life history characteristics together with the utilization of existing data are required. In NSW for example there is some quantitative evidence to suggest that an optimal fire interval range of 10-40 years is relevant to mallee. Management to ensure that at least a sizeable proportion of vegetation in any jurisdiction is maintained within this range may be desirable. Such a management focus should not preclude the necessity for longer intervals between fire, however.

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4. Principles for information dissemination, technology transfer and capacity building

4.1. Background

Communication activities are particularly important in rangelands fire management: fires spread easily so people need to cooperate with their neighbours in managing fire; the tools used to detect and manage fire can be applied across remote Australia so sharing information is useful; effective fire management practice and policy needs a broad awareness and understanding of fire issues. Communication in rangelands fire management therefore, can have various goals which may include building cooperation between fire managers; keeping fire managers updated on good practice; providing information on where fires are; raising awareness and understanding about fire issues for the general public, tourists and schools; informing policy-makers.

Attempts to achieve these goals, however, must take the following factors into account:

- There is a great range of people who have a stake in rangelands fire management. Such diversity in fire management cultures implies that a wide range of approaches is needed for communication to be effective – and this can strain resources.
- Fire management issues can vary considerably between regions in the rangelands due to different vegetation and landscapes, different land-uses, and different cultural, social and economic contexts. This can limit the transferability of information between regions.
- The remoteness, lifestyle and culture of many people involved in fire management means many communication techniques such as mass media, publications and formal training courses are ineffective.
- Even if some groups are inclined to read publications and attend courses, they may not trust the fire research findings such publications and courses are based on because they have not been effectively engaged in the research and development process.
- There are not many fire researchers, communicators or planners in the rangelands so there is relatively little information on fire management and planning compared with southern Australia.

These characteristics of rangelands can hinder the communication activities that are needed to support effective fire management—however, by having adequate resources and by using appropriate strategies many of these limitations can be overcome. For example, the experience gained in the undertaking of various community-based fire management projects in northern Australia over the past decade (many of these involving NHT funding) provides some useful insights. First, such projects have been and are now being undertaken where regional communities themselves have identified significant, often contentious fire management issues—and where different key regional stakeholder groups have been prepared to work collaboratively to address these. Second, projects have been developed collaboratively with stakeholders, typically with independent expert assistance, to:

- address significant regional issues through practical demonstration (or 'action research') activities (e.g. assess effectiveness of aerial control burning; assess use of rotational burning for stock and vegetation management at paddock scales; trial collaborative fire management arrangements to address, and enhance understanding of, across-tenure / across-sectoral issues; build economic capacity of Indigenous fire management teams for delivering property- and regional-scale outcomes);
- develop various useful tools to inform / assist land managers with fire management planning, implementation, monitoring (e.g. develop regional fire history mapping; produce fuel curing guides; develop habitat-specific guidelines, and land-use guides, for promoting sustainable fire management practice);
- build greater community understanding of regional fire management issues, and how these may be addressed, through direct ownership of regional projects by stakeholders as partners, and educational, extension, training, communications, and hands-on activities.

Valuable insights have also been gained from the extensive fire research program carried out by the CSIRO in the savanna woodlands of the NT which has involved a substantial communication effort directed to the general public – the largely urban population across Australia.

The lessons that have emerged from all these projects can be summarized in the need to emphasise the "Three C's"—*building Capacity and awareness*, by providing appropriate tools and information; *fostering Community engagement* by involving the community in the research and *encouraging Cooperation* by getting people to work and learn together. These important elements of fire management can also be used by regional groups and planners and the next section looks in more detail at how they might be implemented more broadly across the rangelands.

4.2. Developing capacity, community engagement and cooperation

4.2.1 Principles of capacity development

Building capacity within a community works well when the process is actively supported by that community. Whether a project is initiated by the community or an outside organisation, there needs to be:

- genuine collaboration between the external organisations and communities;
- a high degree of support from and participation by the community;
- close coordination of the process;
- an ability to work with the community's culture and processes.

Therefore, community capacity development is a deliberate and strategic process of community participation and action where members of the community and the external organisations:

- mobilise existing skills, resources and commitment to build and improve networks;
- reframe problems;
- use community assets in new ways;
- develop new and innovative approaches and skills aimed at building sustainable local communities.

Capacity building, community engagement and cooperation are inter-dependent: for example, building up skills and tools will enable a community to more effectively engage with research and effective adaptive fire management and to more effectively collaborate with other groups.

4.2.2 Respecting values, approaches and views

The marked diversity of environments land-uses and cultures in the rangelands produces a corresponding range of values, approaches and views concerning fire management. For example, Indigenous people burn country for different outcomes to those of pastoralists, miners or tour operators. The widespread low levels of resources in the rangelands and the boundary-crossing nature of fire, however, means that cooperation between these different groups in fire management is often vital – and mutual respect is a key to effective cooperation. Respect for values for example refers to the observation that no one type of fire management is necessarily bad, just different. Mutual respect for different approaches should be a positive outcome of any efforts to collaborate across sectoral interests.

Respect must be earned and often the best way to earn respect is through long-term, often face-to-face, relationships with people who have different approaches and views. Establishing cooperative networks is one way to establish these relationships.

4.2.3 The importance of cooperative networks

Cooperative groups or networks are groups of people who regularly communicate among themselves, formally and informally about aspects of fire management that are of common interest—as opposed to 'audiences' that may be identified for a communication product. If such networks have shared goals, allow for the establishment of good relationships through face-to-face communication, are adequately resourced and have concrete outcomes, they can work well in achieving those outcomes. For example,

if landowners, other fire managers and researchers are brought together to produce regional plans or a booklet on fire management, there is a practical outcome that keeps the group together and the relationships formed as people work and learn together can help bridge the cultural divides within the group.

Some of the challenges of communication in rangelands can strengthen these networks. The lack of people with particular types of fire knowledge can mean networks that draw fire managers and fire researchers together across a region can provide a critical mass of knowledge that is not found elsewhere in that region and is consequently valued by its members. Such networks can also provide their members with rare opportunities to tap into other types of knowledge and views. Remoteness is the big challenge so such networks need to be supported by funding for travel, accommodation, workshops and the like. Considerable knowledge of the cultures and communities involved in these networks may be needed in order to make them work.

4.2.4 Consultation, involvement and action research

It may not be enough to establish cooperative ways of producing practical fire management tools, if fire managers feel disengaged from and mistrustful of the research such tools are based on. This problem must be addressed by the way fire management research is conducted. Research users such as regional groups, however, may be asked to support or may sponsor fire management research.

As outlined above, fire management research should have a collaborative, participatory, action research approach where this is possible. In this approach project partners, participants and communities are directly involved and are given ongoing opportunities to have their concerns and ideas addressed by the research. Cooperative networks of the people involved in the research are created and the research results can become embedded in community knowledge.

If participatory action research is not possible then technology transfer that allows people to see how tools work in the landscape, such as demonstration plots and field days, and that uses face-to-face communication is usually far more effective than publications, websites or videos. It is also mindful that when consideration of these tools are developed, that Indigenous people may have special needs in relation to communication due to different languages being spoken and the need to be innovative in developing these tools.

4.2.5 Indigenous communities

Indigenous people play important roles across many sectors and do not necessarily see themselves in the ‘Indigenous sector’. However Indigenous people are placed to have an increasing role in the active management of landscapes in the rangelands of Australia. For this to occur there needs to be development of capacity for Indigenous people to be fully engaged in regional planning initiatives from the very beginning of discussions about planning. It would also be expected that Indigenous people have a role in most if not all of the regional groups situated in the rangelands. It is mindful and respectful to engage Traditional Owners with Native Title interests in country that may be under management or is being managed by another leaseholder.

The regional processes for engaging Indigenous people into NRM planning should also consider the ‘Best Practice Framework Guidelines for Advancing Reconciliation’ available online at:

<http://www.affa.gov.au/content/output.cfm?ObjectID=E2AC35D1-6A00-4224-A7048608989E6627>

Some broad principles for engagement with Indigenous communities:

- Mutual engagement at the very beginning (having access and opportunities to address issues within a holistic framework (mix of quadruple bottom line – cultural, social, economic and biophysical outcomes)
- Employment (possibly CDEP as a foundation, but with top-up that should lead to ‘real’ employment outcomes).
- Well networked i.e. within Indigenous sector (Land Councils, CDEP, Community Councils, Associations and Corporations) but importantly outside it—resource providers (BFC, RFS, State Parks and Wildlife Authorities and others)

- Mutual respect and use of cultural knowledge in the management of country (using a two-tool-box approach of Indigenous Knowledge and Western Knowledge) that can compliment each other as separate knowledges.

4.3. Communication initiatives

If the approach to communication and knowledge transfer described above is taken, then the following specific initiatives can be used to achieve better fire management in the rangelands. Even if it is not feasible to implement all aspects of the approach above (e.g. the available R&D tools may not have been developed using participative methods) it is still worthwhile developing networks, or tapping into existing ones as outlined above, and then using one or other of the initiatives below.

- *Ensure good access to information.* The lack of accessible rangelands fire management information means that it can be important to provide relevant on-going information and communication resources for people interested in these issues. Thus fire managers can be provided with—or directed to—summaries of fire management issues, checklists for fire management planning, bibliographies of relevant research etc. Policy makers can be directed to convenient summaries of research—as can the media (but both these groups are unlikely to use such resources unless you have developed networks with them).

A key point here is that the great variety of people involved in rangelands fire management implies that a corresponding variety of media may be needed to provide information to these people—some will use websites, others email, others newsletters and some in Indigenous media/languages etc. This variety also implies that the form of communication may need to vary—some groups will appreciate check lists, others may relate to visual media or oral communication rather than text, others may appreciate information in a narrative form rather than as a set of dot-points. With limited resources you will need to prioritise what groups you need to provide information to. If you are linked to networks representing these people, then they can be used to help gather this information, offer advice on how it should be best presented, and can help spread the word about these information resources.

- *Provide access to communication tools.* Cooperative networks of people can be used to produce more ambitious fire management communication tools such as websites that help track fires (like the NAFI website) or fire management resource books etc. These are essentially just advanced forms of information, but the word tool emphasizes information that is used repeatedly to achieve practical outcomes. Such information or communication tools that draw on the pooled knowledge of researchers and research users can combine practicality and innovation. Producing the more ambitious tools that can be used across the rangelands may require collaboration across regions, however a useful tool may be something as simple as a grass fuel guide that can be produced by a regional group. You should be aware of all such tools from various regions of the rangelands that may be useful in your region—or that can be easily modified.
- *Provide training and demonstrations.* Given the lack of human resources in rangelands, capacity-building in the form of training and demonstrations can be vital. This could include cross-cultural training for people working in R & D groups or training and demonstrations for fire managers in using R & D tools – so they are better able to use these tools and better able to offer feedback that will allow such tools to be improved. It is mindful to include Indigenous interests in these events and in some case there may be a need to target Indigenous field days to support local capacity development before interaction with other sectoral groups occur. Often face-to-face communication and hands-on experience is best. Such training may require resources such as dedicated employees, workshop or field day costs, travel and accommodation costs.
- *Support communication in networks.* The lifeblood of collaborating networks of people is ongoing communication between its members. If you have set up a network, it may be necessary to support this communication by providing email or paper newsletters, a news website etc. to keep people updated on projects, informed of new tools and dates for useful meetings. In other cases it may be more efficient to contribute to the newsletters of existing networks such as land management agencies, and Landcare groups. Existing networks may also be important in distributing publications, as the distribution networks for publications are quite sparse in the rangelands.

- *Help communities help themselves.* For Indigenous communities in particular, creating more opportunities for people to be out on country can be a great help in fire management. Many Indigenous communities, for example, have elders with a rich knowledge of traditional fire management who need to be given more opportunities to be with younger community members 'on country' to impart this knowledge effectively. These practical 'back to country' initiatives are proving to be positive solutions in knowledge conservation. Working with and supporting the Indigenous ranger groups across north Australia can be one way to support this process.
- *Network with policy makers.* Good fire practice is often difficult to implement without good fire management policies and laws. Involving relevant policy-makers and advisors in fire management networks can be important. Unless policy makers and advisors know and trust particular people or organisations as reliable and useful sources of information they are unlikely to stumble upon and use your fire management information, regardless of its quality. Policy makers can be involved in planning and policy-focused groups.
- *Use the mass media.* Raising awareness of fire management issues in the broader community through the mass media can be useful – for example in getting across simple messages about fire, establishing fire management as an issue that needs to be taken seriously, or publicizing an initiative. The media used can range from local radio and newspapers to national newspapers and TV, depending on the audience you want to reach. It is often easier - and very useful in regional settings, to get coverage from the local media about local fire management issues – as the relevance is clear and often local media are looking for content. Getting coverage for rangelands fire management in the national media or TV can be more difficult.

Caution should be used when dealing with the mass media, particularly at the national level and in its very popular forms. At this level the mass media may well choose to emphasise particular aspects of any bushfire story it hears about—such as the conflict and drama in the story – for the sake of appealing to a very broad audience. Such an approach may do more harm than good for rangelands fire management. Developing good relationships with the journalist concerned can help minimize this risk.

- *Engage with the education system.* Having a broader community that is well-informed about rangelands fire management has many longer term benefits for fire management: by creating better-informed public debates; encouraging well-informed policies; producing better informed fire managers. This outcome is best achieved through the education system. At the regional level you can work with local schools or TAFEs to help them provide better information on fire. Longer term solutions will involve working with the state or territory education departments where collaboration with bodies across regions may be needed.
- *Evaluate communication.* These communication initiatives need to be regularly evaluated to see if they are working. This can be done using consultants to conduct reviews, using media monitors, statistical packages on websites and regularly sending out feedback forms and questionnaires. Often, however, some of the most reliable feedback comes from word of mouth through the various fire management networks.

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5. Criteria for setting priorities for development of fire management plans

All regional bodies in the rangelands will need to address fire management as part of the regional NRM planning process, although it is recognised that fire management will form a higher priority in some regions and broad vegetation types than in others. However, even in the few rangeland regions where wildfire is relatively infrequent or restricted in its occurrence (e.g. chenopod shrublands), there will still be particular locations and contexts that demand a planned approach to fire management.

Planning for biodiversity conservation requires consideration of existing international, national and Territory initiatives, strategies and legislation, including those listed below:

- Environment Protection and Biodiversity Conservation Act 1999
- National objectives and targets for biodiversity conservation 2001-2005 (Environment Australia 2001)
- National Strategy for Ecologically Sustainable Development (1992)
- Australian National Strategy for the Conservation of Australian Species and Communities Threatened with Extinction (Endangered Species Advisory Committee 1992)
- National Forests Policy Statement 1992
- Nationally agreed Criteria for the establishment of a comprehensive, adequate and representative reserve system for forests in Australia (JANIS 1996)
- National Strategy for the Conservation of Australia's Biological Diversity 1996
- National Greenhouse Strategy 1998
- National Principles and Guidelines for Rangeland Management (Australia and New Zealand Environment and Conservation Council ANZECC, and Aqriculture & Resource Management Council of Australia & New Zealand ARMCANZ 1999)
- Australian guidelines for establishing the National Reserve System (ANZECC 1999)
- National Framework for the management and monitoring of Australia's native vegetation (ANZECC 1999)

The identification of priority regions for fire management is predicated on two assumptions. The first is that the information base, as it relates to occurrence and impact of fire in the rangelands, is adequate to make inter- and intraregional comparisons. This is only partly true in a very limited number of locations. The second assumption is that there exists a set of rules or principles that enable choices between different options for prioritisation. A simple example of such a choice is that between investment in maintenance of habitats or ecosystems that are currently in good shape but under imminent threat of deterioration in the face of poor or inadequate management, and investment in arresting the decline of already degraded systems. Such choices must also take account of the likelihood of intervention having a significant impact, or 'return on investment'.

Therefore, rather than developing a list of priorities based around the perceived gap between need and current action in rangeland fire management, we have identified a set of more general principles that should assist future prioritisation both within and between regions.

5.1. Information

As a first principle, it will be necessary for all regions to have access to adequate baseline information, ideally within the next few years. Current spatial information resources and future priorities are discussed elsewhere in this report, but should include, in simple terms, mapping of fire occurrence and vegetation at spatial and temporal scales appropriate to the region in question.[1] This should also include some capacity to identify areas with adverse fire regimes, i.e. regimes that are inappropriate to achieve regional objectives, at inter- and intra-regional scales.

[1] For example, temporal scales for fire mapping need to encompass longer periods for arid rangelands than mesic savannas.

Projects that provide baseline information that will lead to capacity to make judgements at inter/intra regional scales should be given priority, so consideration needs to be given to benchmarking projects within and between regions so that such comparisons can be made.

Traditional Owners who hold baseline Indigenous Knowledge information that would be of use to managing fire in the rangelands should be engaged where possible. Engagement with existing and emerging Indigenous groups may be required. It is important that this knowledge is not overlooked; Indigenous perceptions on managing country should be incorporated in land management planning.

Some Indigenous groups may also require more practical and appropriate access to information and attention to language should be considered and resourced. Language provides a strong basis for the retention and transmission of traditional Indigenous Knowledge that can contribute to improved land management.

5.2. Geographic spread

From a whole of rangelands perspective, it will be desirable to establish a good geographic spread of working cases, including the three rangeland fire syndromes identified previously. There should also be a spread of initiatives that encompass the major sectors and land tenures (e.g. pastoral lands, Indigenous owned lands, the conservation estate) recognising that sectoral interests may overlap.

5.3. Transferability

All else being equal, projects or management plans that promise to be more generally applicable within and between regions should be given a higher priority. This includes projects that have the capacity to demonstrate a principle or strategy to a wider set of locations or regions.

5.4. Time-critical projects

Initiatives should be given priority that address habitats or species threatened because of fire regime / inappropriate fire management, or where improved fire management will increase the prospects of a threatened habitat or species. This may also include those places where valuable Indigenous Knowledge remains available—in this case engagement is time-critical due to the rapid declines in the number of Indigenous Knowledge holders with experience in traditional land management (elders).

5.5. Return on investment

Greater priority should be recognised where changing fire management will clearly improve a currently undesirable situation—i.e. benefit / cost of fire management proposed. Further priority should be assigned to plans/projects that integrate fire with other NRM issues such as weeds and feral animals and also cultural issues such as managing sacred sites. Where possible, plans should aim to get multiple benefits and therefore the best return on NHT investment from integrated sets of activities.

5.6. Capacity

Finally, consideration should be given to the investment required to strengthen the capacity to deliver on fire management for biodiversity and/or production outcomes in each region. Capacity building should be considered as an outcome additional to direct gains through fire management, off-setting what may seem to be initially slow progress on improving fire management outcomes. Fire management is a continuous process requiring an ongoing and adaptable human presence in the landscape. In some parts of the rangelands, it is beneficial to consider ‘other’ aspects of fire management such as Indigenous values, uses and outcomes of fire management.

It is often beneficial to develop initiatives around human capacity catchments, that is, working from where the largest human presence is, developing capacity within that community then working outwards using available resources.

6. Information requirements and critical knowledge gaps

This section identifies a number of critical knowledge gaps, which we feel need to be addressed throughout the Australian rangelands if sustainable fire management is to be delivered. While various knowledge gaps have been identified throughout this report (e.g. information requirements for effectively managing major vegetation types in Section 4), we emphasise here a select number of generic issues as follows:

- developing inclusive community engagement
- key information needs
    - fire mapping products
    - assessing fire risk
    - vegetation, and flora and fauna species mapping
- species responses to fire regimes
- implementation issues
    - how to implement fire mosaics for creating habitat heterogeneity
    - monitoring and adaptation

6.1. Community engagement

A key to developing and delivering appropriate and informed fire management in various rangeland landuse settings depends on building (or using existing) collaborative networks, fostering active participation in ‘action research’ (i.e. learning through practical experience) initiatives, and establishing effective means of communication—in other words, engaging the community (see also Section 4). This is more easily said than done—it certainly requires more than simply revisiting traditional modes of ‘extension’ (e.g. addressing focal group workshops), targeted training, and ‘communications’ (e.g. providing research reports)—nevertheless, such activities also have their place.

As described in Section 4 the success of several community-based fire management projects across north Australia has been partly due to an emphasis on capacity-building, community engagement, action research and collaboration. That experience, we suggest, has relevance to other regional communities in the rangelands that face similar broad-based issues. However, while lessons from north Australian projects doubtless provide useful comparative examples, it is clear from the foregoing discussion that practical experience with, and engagement of, regional communities in dealing with their own fire management issues cannot be duplicated. Developing engagement and empowerment of regional communities is thus a first and critical gap.

Other specific engagement issues which require further addressing include:

- *Indigenous involvement*—recognising significant cultural, language, literacy, educational, and often simply resourcing issues / impediments to participating in community fire management endeavours, including accessing, and contributing to, pertinent information sources. How to better engage Indigenous participation is a fundamental issue and is discussed in the National COAG Bushfires Enquiry report (Ellis et al. 2004).
- *education issues generally*—incorporating pertinent information resources into accessible environmental curricula materials, particularly at primary and secondary school level. To date this issue has remained very under-addressed—but there is a recent initiative undertaken in NT, aimed at upper primary-lower secondary schools and involving CSIRO, Greening Australia, the NT Govt. and TS–CRC. Note that this issue has also been considered in the COAG National Bushfires Enquiry report (Ellis et al. 2004).
- *informing policy*—a major information / credibility gap continues to exist between rangelands land/fire managers and those responsible for developing (and hence practice of) regional, state/territory, and national fire management policy. We note that, while some progress has been made in this regard with the recent publication of the COAG National

Bushfires Report (Ellis et al. 2004), substantially more needs to be done to better inform policy makers of the extent and significance of bushfire and related management issues in rangelands Australia.

6.2. Information issues

6.2.1. Fire history and fire mapping

Fire mapping information products, derived from satellite sensors, are required to inform (a) real-time incident management, and (b) assist with longer-term, strategic property- and regional-based fire management planning. Currently, fire mapping products are available on the internet as follows:

- daily continental locations of fires, or ‘hotspots’, can be accessed through WA’s Department of Land Information (DLI; <http://firewatch.dli.wa.gov.au>and CSIRO’s Sentinel <www.sentinel.csiro.au> sites or, for northern Australia, the North Australia Fire Information (NAFI) website of the Tropical Savannas CRC (TS–CRC; <www.firenorth.org.au>
- fire map products, providing historical information on the locations of fires for the last few years at least, are currently available on the DLI and TS–CRC sites. These sites also provide simple GIS tools to download fire data, and integrate that information along with other map coverages (e.g. topographic maps).

Below we outline the status of the availability of fire mapping products derived from satellite imagery for use in Australia’s rangelands, and indicate some current developments which will assist with delivery of more reliable, more timely products. As outlined in the COAG National Bushfires Report (Ellis *et al*. 2004) the further development of such fire mapping products, and their uptake by regional communities, is a recognised national priority.

Fire history from satellite images

NOAA AVHRR satellite images have been used to provide a broadscale perspective on fires for the past decade. The TS–CRC and Western Australia’s Department of Land Information have compiled a continental fire history database for the seven-year period from 1997 to 2003 (Figure 1.3). Such imagery has been used to a limited extent to assist management programs on large pastoral properties and national parks, and provides significant input to fire suppression activities. It has serious limitations associated with its coarse spatial resolution (misses small fires and has +/- 1–2km spatial accuracy), but has the advantage of high temporal resolution. Fire history updates are usually created on the 9-day satellite orbit cycle, but can be generated more frequently if required.

The MODIS sensor on the Terra and Aqua satellites offers a new alternative, with higher spatial resolution (250 m instead of 1km), and a similar temporal resolution to AVHRR. It has been available since 1999, but image reception and data processing within Australia has proceeded slowly and it still has yet to effectively replace AVHRR although the TS–CRC NAFI site has been displaying MODIS fire scars for the NT and north Queensland for several months and feedback suggests these scars have been useful to fire managers. Expansion of this area of activity is needed.

Landsat and other relatively fine resolution satellite images (e.g. Landsat ETM with 30 m pixels) have been available in Australia to produce detailed fire history datasets for 25 years. However, due to the relatively high cost of images, fire history datasets are available for only a small portion of the rangelands. These areas are primarily associated with national parks or other relatively small project areas and can be complemented with data derived from air photos and ground-based mapping. The most extensive datasets occur within the NT (Figure 6.1, Table 6.1).

The Australian Greenhouse Office (AGO) carbon accounting program compiled a spatially registered Landsat image dataset for the majority of Australia in 12 timeslices between 1972 and 2002. For the areas of Australia without a high fire frequency, i.e. outside the tropical savanna regions, it offers an opportunity to create a finer scale fire history, however considerable effort will be required to process the images.

Continental fire history in relation to major climate/fire regions

The 1997–2003 continental fire history database provides an overview of fire history and fire regimes within the major climate/fire regions defined in Section 3.2, viz. tropical savannas, semi-arid and arid interior, southern temperate regions. Temporal and spatial scale fire history issues vary across the 3 continental regions but the limitations of its seven-year perspective and its spatial resolution need to be appreciated at the outset. It is most robust for the tropical savanna regions that have a reliable annual rainfall and a short fire cycle. It highlights the dominant occurrence of fires in northern Australia and extensive fires in central Australia during periods of relatively high rainfall. Spatial resolution limitations in Figure 1.3 are most significant in rural/urban interface areas and areas of intensive fire management, such as Kakadu National Park. The seven-year history shows some annual variability but is very unlikely to have captured the full extent of even contemporary variability. For the semi-arid and arid regions of central Australia, the 1997–2003 database captured the extremes of a 30-year fire cycle. It began during a period of low rainfall (1995–1999) with a relatively small area burnt. It also included a three-year period of above-average rainfall and extensive fires (2000–2002). The fires in 2003 were mainly in forested area outside the rangelands but included some mallee country in the rangelands and were the most extensive fires in south eastern Australia since 1939, covering 3 million hectares. The 1997–2003 database does not provide adequate information to characterise the ‘average’ years with the 30-year fire cycle and summary statistics on fire regimes for this region must be used cautiously.

The 1997–2003 fire history shows very few fires in the southern temperate region of Australia, despite the occurrence of several fires that burnt into urban areas and attracted intense media coverage and international attention. The coarse resolution of the dataset misses small fires in more intensively settled and managed rangeland areas. Fires are actively suppressed in these areas, are frequently restricted to roadside and road reserves, or are completely absent due to high grazing pressure and absence of fuel. Fires in more rugged landscape areas on the SE margins of the rangelands are less likely to be detected or adequately mapped due to vegetation characteristics, terrain complexity, clouds and shadow. Similar to arid regions, the fire cycle operates on a long temporal cycle although the 1997-2003 period did coincide with a period of high fire risk and extensive fires. In these landscapes high fire risk is associated with drought rather than periods of above-average rainfall in the arid lands. For example, major fires in semi-arid mallee in the south east occurred in 1997 (Ngarkat Natioanl Park in South Australia) and late 2002 (Big Desert Wilderness, Victoria) which were coincident with severe and prolonged drought. There is a need for moderate and high resolution mapping programs to more adequately capture the fire regimes in the southern temperate region.

6.2.2. Assessing fire risk

Fire risk assessment requires the timely collation and interpretation of a diversity of spatial datasets. Although some of the basic datasets required are available for some states, a complete set for Australia has not been compiled. The understanding and models needed to derive ancillary information, and to calculate risk, are also lacking. Simple models and/or rules of thumb are generally based on experience of local land managers. The perceived level of risk is based on experience, generally biased to most recent years and influenced by local conditions. Risk assessment is not only valuable during periods of high fire danger but can provide information to improve the timing of strategic management. In tropical savannas, reducing annual risk at the end of the dry season when fire weather conditions regularly reach extreme levels requires timely use of fire to manage fuel loads during the early part of the dry season, without compromising either biodiversity or productivity values.

In central and southern semi-arid and arid regions, rainfall has been used as a simple surrogate for fuel load accumulation and risk because grass and herbage fuels are significant fuel components in many vegetation types. Better models of pasture production for a range of vegetation communities incorporating grazing impact, plus a more extensive network of rainfall recording stations, are required. Developing programs applicable across the extensive interior region is also a major challenge. Notably, there are major vegetation types, such as mallee, where litter and foliage of perennial species is the principal source of fuel. Fuel accumulation models indicating trends in fuel mass in relation to time since fire are needed to predict the status of these fuels. Availability of these fuels to burn, is strongly influenced by fuel moisture, which in turn are influenced by rainfall and soil moisture as expressed in various drought indices. Large fires, and hence risk of fire at a point in the landscape, are therefore linked to drought. There is currently little information on fuel accumulation patterns in some of these vegetation types, though regional information on drought indices is provided by the Bureau of Meteorology.

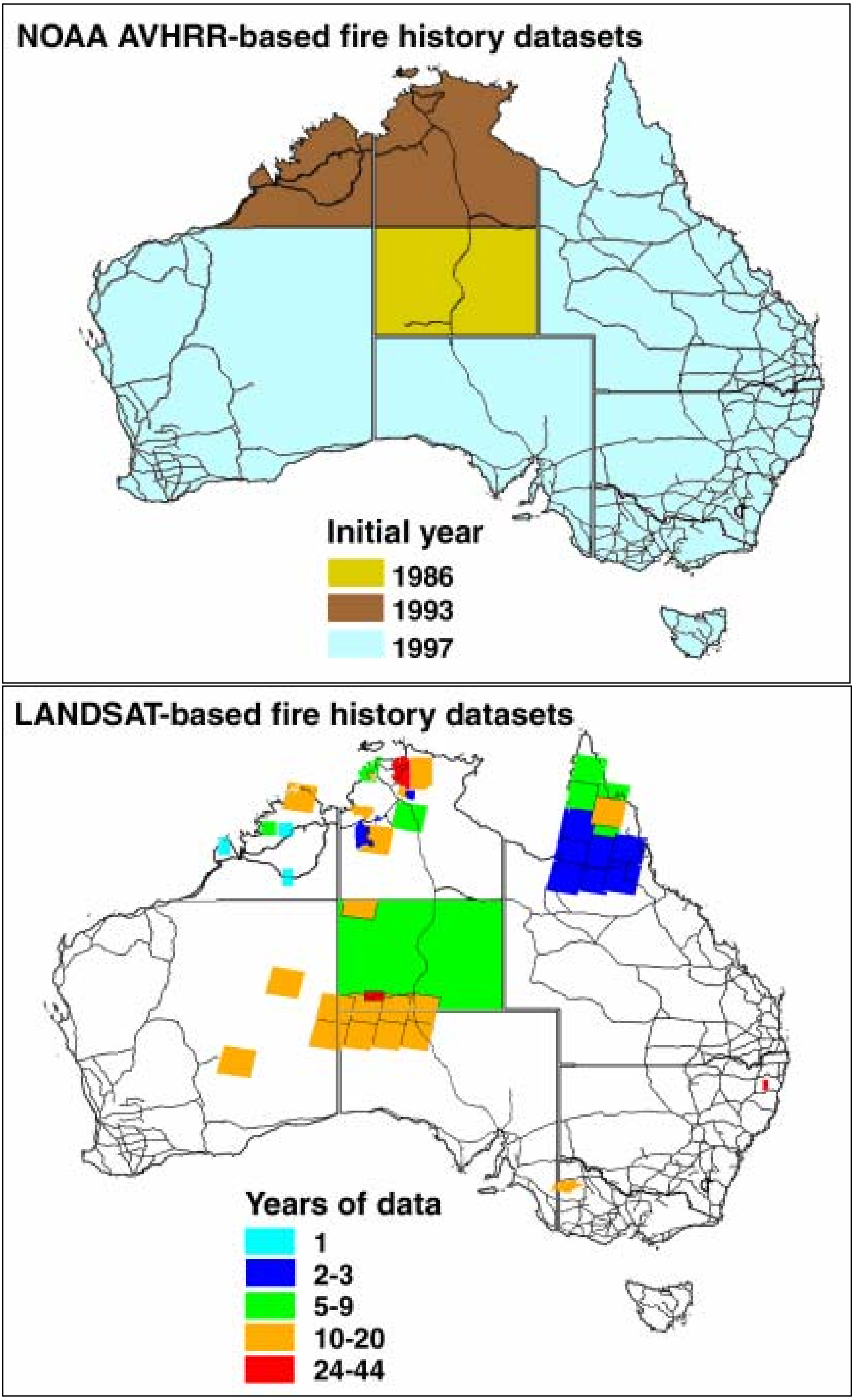

Figure 6.1 Aerial extent of fire history databases

Table 6.1: Summary of fire history databases

Area	State	No. Years	Years	No. Scenes	Landsat_WRS	% Scene Area	Data_Source
Beagle Bay Peninsula	WA	1	2001	1	110/72	25	Landsat TM
Mt Elizabeth Station	WA	1	2001	1	108/71	25	Landsat TM
Bohemia Downs	WA	1	2001	1	108/73	25	Landsat TM
Queensland Gulf	Qld	2	2002–2003	7	98/71–96/73	100	Landsat TM Quicklooks
Jawoyn Lands	NT	3	1996–1998	3	104/70	20	Landsat TM
Gregory NP	NT	3	1999–2001	2	106/71–105/71	40	Landsat TM
Cape York Peninsula	Qld	5	1999–2003	4	98/69– 98/70	100	Landsat TM Quicklooks
Bachsten Creek	WA	5	1998–2002	1	109/71	100	Landsat TM
Sturt Plateau	NT	6	1995–2000	1	104/71	100	Landsat MSS and TM images
Central Australia	NT	7	1978–1985	30	105/74–100/78	100	Landsat TM 1:1M Transparencies
Darwin	NT	9	1993–2001	1	106/69	60	Landsat TM
Kalumburu	WA	10	1993–2002	1	108/70	100	Landsat TM
Bradshaw Defence Lands	NT	12	1990–2001	2	106/71–105/71	40	Landsat TM
Ngaanyatjarra Lands	WA	13	1990–2003	1	107/77	100	Landsat TM Quicklooks
West Arnhem Land	NT	14	1990–2003	1	104/69–70	100	Landsat TM
Lichfield NP	NT	14	1990–2003	1	106/69	20	Landsat TM
Nitmiluk NP	NT	15	1989–2003	2	105/70–104/70	20	Landsat TM
Laura Basin	Qld	17	1987–2003	1	97/70	100	Landsat TM
Great Victoria Desert	WA	18	1972–1994	1	108/80	100	Landsat MSS
VRD	NT	18	1983–2000	1	105/71	100	Landsat MSS and TM images
Tanami / Granites	NT	18	1979–1996	1	105/74	50	Landsat MSS prints, Landsat TM images
Big Desert	Vic	18	1979–1997	1	95/85	40	Landsat MSS and TM images
APY Lands	SA	20	1984–2003	8	105/78–102/80	100	Landsat TM Quicklooks
Kakadu NP	NT	24	1980–2003	2	105/69 + 104/69	50	Landsat MSS prints, Landsat TM images
Guy Fawkes NP	NSW	25	1977–2001	1	89/81	10	Landsat MSS and TM images
Uluru NP	NT	44	1950–2003	1	104/77	20	Air photos, Landsat MSS prints, Landsat TM images

In temperate forests and woodlands, litter and perennial foliage are the main source of fuel. These follow regular patterns of accumulation after (Walker 1981, Raison *et al*. 1986), hence time since fire is used as a predictor of fuel load. Fuel availability is a function of fuel moisture, and in turn, weather. Information on drought status (drought indices) is an important component of fire-risk prediction (see above).

More complex models are required, incorporating a diversity of spatial datasets, including:

- rainfall, as a combination of point-based records and interpolated surface grids.
- climate information, including seasonal trends, temp, wind and RH, ENSO SOI, solar radiation.
- topography.
- fire history.
- vegetation type, generalised across Australia, but with local/regional variations; typically with a bias toward ground vegetation/fuel type.
- curing state.
- pasture production models by major vegetation type.

Risk assessment can function at a variety of levels; from general seasonal conditions operating across state or regional extents at fortnightly to monthly intervals, to specific incident conditions operating at sub-region or land management unit level at hourly to daily intervals. The seasonal conditions can be considered in a prescriptive context, whereas the specific information is more operational.

Projects within the USA are contributing to the development of risk assessment programs. However risks can only be adequately assessed following the development of resource layers. Individual layers include vegetation maps, fuel maps, fire effects and fire regimes. Each of these layers is built from a series of other data layers and developed for a range of scales, from a coarse scale applicable at the continental level, through medium and fine-scale layers. The US Forest Service in combination with other agencies has programs addressing each resource layer (Bobbe et al. 2001, Hardy et al. 2001, Reinhardt et al. 2001, Morgan et al. 2001) as well as addressing their compilation into risk assessment. Some programs are being developed within individual Australian states (e.g. Risk Management Planning in NSW) but a national program has yet to be undertaken.

6.2.3. Vegetation, and key flora and fauna species mapping

Various sections of this report have alluded to the need for more detailed mapping of vegetation (including more fire-sensitive assemblages which often form part of the matrix of more widespread types), and key fire-sensitive flora and fauna species. Further work on all these aspects is clearly required to inform regional fire management planning and implementation.

Some spatial information about the distribution of many fire-sensitive vegetation types is available, though not always at a sufficiently fine scale resolution for accurate geo-referencing. This is partly because the small area occupied by many vegetation patches cannot be resolved at the scales of mapping currently available. For example, the best scale of vegetation mapping available for much of the rangelands is 1:1 000 000. Mapping at this scale can show only the dominant vegetation association occurring over relatively large areas. Small areas of different vegetation within the dominant matrix may be referred to in map legends (e.g. a vegetation type might be described as “tropical eucalypt woodlands with pockets of rainforest”) or can sometimes be inferred by biophysical association (e.g. an association between riparian vegetation and major river systems, or heath vegetation with rock outcrop). It is also possible to make inferences about burn mosaics in widespread vegetation types from fire-scar mapping, which can be undertaken from satellite-based monitoring and is routinely available for Western Australia, the Northern Territory and much of northern Queensland.

Despite being able to make inferences about where many fire-sensitive vegetation types may occur and the fire regime experienced in the landscape around them, there are significant knowledge gaps about current status and plant population trends in many of these vegetation types. Mapping of fire-sensitive vegetation, key habitats for fauna, and fauna distributions generally, is thus a critical priority for informing better land management.

6.2.4. Species responses to fire regimes

Another key issue noted in various sections of this report is the lack of available information concerning species' responses to different components of fire regimes. As noted in 3.1.2 there are key features (attributes) of the biology of plant and animal species that determine responses to fire regime components such as fire interval, intensity and season. Survival ability, reproductive rates, life spans and dispersal capabilities differ widely among species, hence responses to fire regimes vary widely. Different species exhibit different combinations of these features or attributes. For example, some species of plants characteristically re-sprout following fire while others do not. Some plants possess seeds that are reliant on heat, smoke or other fire-related mechanisms for germination. Storages of seeds and their vulnerability to fire vary widely among species. Variation in these attributes can occur even among closely related species. The scientific study of this variation, its evolutionary origins and its ecological significance has a long history. Such knowledge is of great practical importance and can form the basis of generalizations that can assist decision-making and guide monitoring in fire management.

As already noted also in Section 3.2, schemes exist (e.g. Noble and Slatyer 1980, Gill 1981, Gill and Bradstock 1995, Noble and Gitay 1996) for defining the sensitivity of plant species to various fire regime components, based on systematic appraisal of key attributes. To date, no systematic functional classification of the responses of fauna to fire has been developed, although Friend (1993), Keith et al. (2002) and Whelan et al. (2002) have identified some of the ecological and life-history attributes that are important in determining the response of vertebrates to fire. Shelter type, foraging patterns (activity substrate), mobility and breadth of diet are key characteristics, and may be regarded as primary attributes.

In contrast to many plants, the functional equivalents of dormant seeds or ability to re-sprout are lacking in higher vertebrates: if a species is eliminated from a patch or area by any particular fire, recovery will be dependent on dispersal from elsewhere. In this sense many animal species may be characterised as being dependent on dispersal for maintenance of a population at a point or patch in a landscape. Such species may persist in landscapes by avoiding fire in refugia and by avoiding unsuitable post-fire conditions. Additionally, however, a high degree of mobility in animals (e.g. the ability to move daily or seasonally) may allow many species to use burnt areas provided these are adjacent to refuges (such as rock outcrops) that provide critical resource/s. Characterisation of the ability (or dependence) of an individual to regularly use different habitat elements remains a central issue in the development of a functional classification of animal responses to fire.

Attribute databases

There is considerable national activity focused concerning the definition and collection of information on key attributes of plant and animal species in relation to fire. A number of attempts have been made to establish comprehensive plant/fire attribute databases (e.g. Gill and Bradstock 1995, Morelli and Forward 1992) and there has been much recent consolidation and expansion (e.g. Bradstock et al. 2004). Work is underway in the Northern Territory to develop a comprehensive plant species response database (see Section 6.3.2), and there is considerable potential for extending this work to other parts of the tropical savannas. Some attempts have been made to establish equivalent databases for animals (e.g. Bradstock et al. 2004) but available information is limited.

The structure of the NSW fire response databases is an example of the type of information that can be used to construct a comprehensive overview. It is emphasized that not all types of information are available for any particular species. Information may only be partial at any given time hence many fields may remain blank. Even a partial overview of a species characteristics may, however, be of value. Often observations on species responses will vary, reflecting inherent variation among populations and perhaps observers. Procedures for vetting the quality of information that is included in databases are therefore important.

Fauna

Relatively little information is available concerning interactions between fire regimes and key faunal species. As discussed elsewhere in this report, it is probable that fire regimes producing a fine-grain patchy mosaic of habitats are likely to support a greater diversity of rangeland fauna than more uniform fire regimes. However, there are too many differences - in fire climates, vegetation types, and resource requirements and mobility of fauna - to allow meaningful generalisations about the optimum nature

and size of habitat patches, hence burn regimes, for particular species. Most studies of the fire ecology of animals have been concerned mainly with several effects (time since fire). They have generally shown that some species favour recently burnt areas and others favour long unburnt areas, which supports the generalisation that diversity is likely to be maximised under mosaic burning, but adds little to the paucity of knowledge about optimal spatial and temporal fire regimes for individual species.

What is known is that many small and medium rangeland mammals are now endangered or extinct on the mainland, and many rangeland birds are declining in abundance and distribution. In the tropical savannas this decline is most apparent amongst seed-eating birds and current surveys indicate a potentially comparable decline in many small mammals. While changed fire regimes are almost certainly implicated in some these declines, it is usually difficult to disentangle fire effects from those due to the range of other factors that typically coincide with changes in fire regimes, most notably proliferation of exotic fauna and pastoral land use. In spinifex landscapes, for example, mosaic burning appears to be important for maximising the diversity of small mammals, reptiles and birds, but less important for medium-sized mammals. In tropical savannas, mosaic burning appears to be important for many seed-eating birds but its role in the current decline in small mammals is uncertain.

In general, therefore, detailed studies of interactions between declining faunal species and fire regimes are a priority for rangeland fire research. Only a few species, such as the golden-shouldered parrot and Gouldian finch, have been studied in sufficient detail to postulate optimal fire regimes for their conservation. For species such as these, the greatest knowledge gaps now relate to implementation and testing of these postulated regimes.

6.3. Implementation

6.3.1. Implementing the mosaic

A central theme of this report concerns recognising the variable needs of regional rangeland biotas and constituent species, and interactions between these with fire-created spatial and temporal mosaics. Thus, it stands to reason that homogeneous ‘fire landscapes’ (e.g. those which are frequently, intensively burnt or, conversely, unburnt over long periods), are unlikely to be as species diverse as those landscapes where extensive fire patchiness / heterogeneity exists. Even in situations where (a) the development of fire-created mosaics is recognised as necessary for maintaining regional biodiversity (e.g. large protected areas), and (b) some understanding of appropriate variability with regards spatial and temporal patterning for targeted species / habitats is available, the implementation of fire mosaics remains largely elusive in practice. For example, despite substantial resources being given to the implementation of a “patch mosaic” burning program over the past 25 years or so in Kakadu National Park, and despite some notable successes in increasing the level of patchiness and heterogeneity over that period (Russell-Smith et al. 1997; Edwards et al. 2003; Price et al. 2004), the total extent of lowland savanna unburnt for more than a few years remains pitifully small (Russell-Smith et al. 1997; Andersen et al. 2004).

As such, any applied fire management research or activity that has, as one of its aims, the delivery and documentation of greater spatial and temporal patchiness at landscape scales, is to be encouraged. A specific case which affects at least the extensive rangelands of central and northern Australia, concerns developing and delivery of effective aerial control burning (ACB) programs. In these regions ACB is often the only cost-effective, practicable means for implementing strategic regional fire-breaks, and/or landscape-scale patch-burning (e.g. Burrows and van Didden 1991; McGuffog et al. 2001). While the NHT has to date supported a number of trials of ACB in northern Australia (e.g. fire management programs in the Kimberley, Arnhem Land, VRD, Cape York), much more work is required in different regional landscapes to assess the efficacy of such practice.

6.3.2. Monitoring and adaptation

In other parts of this report we have emphasised, as first critical steps in the delivery of effective fire management, the importance of engaging the community, providing relevant and reliable liable information sources, and developing appropriate fire planning. The undertaking and further refined development of ecologically sustainable fire management in respective NRM rangeland regions requires that monitoring and adaptive processes be put in place. This is no easy task and, we suggest, at large regional scale has to date not been undertaken effectively in Australia’s rangelands. To be done

properly, monitoring can consume considerable resources. For example, a recent estimate of the cost of the fire monitoring program undertaken in Kakadu National Park (involving satellite mapping of fire extent, and vegetation and fauna monitoring at 134 plots) was $140,000 p.a. (about 1% of the Park's annual budget; Edwards et al. 2003). Work on developing effective monitoring and adaption processes is clearly a priority issue.

We suggest, however, that there are / may be possible cost-effective solutions. While only in its infancy, a fire monitoring program is being developed for the Northern Territory which essentially involves:

- ongoing daily fire monitoring, and monthly fire mapping, derived from satellite sources, for the NT—all being delivered to the community over the internet;
- attributing plant species' responses to fire regimes for the whole NT flora—the first draft is, at time of writing, now complete;
- using that attributed species list, and the availability of a linked NT-wide vegetation database comprising 8000 plots, mapping of 'fire sensitive' habitats in the NT—i.e. those habitats / land systems with large numbers of longer-lived (i.e. those typically taking at least three years to attain maturity) obligate seeder species;
- development of ongoing reporting mechanisms to the NT Landcare Council (the NT Regional NRM body), and individually to each of 10 NT community-based Bushfire Council Regional Committees (each legislatively charged with overseeing fire management in their respective regions), concerning the extent of fire / wildfire with respect to mapped assets, including fire-sensitive communities; and
- with this information, responsible fire management committees in the NT will be able both to monitor fire occurrence in respective areas of responsibility, as well as be in position to intercede, in timely fashion, if situations appear to warrant interventionary action.

The above program attempts to provide both better information, as well as a process of accountability. Much more development of cost-effective monitoring programs, which include timely provision of information for effecting adaptive processes, is required.

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7. Appendix 1

7.1. IBRA Bioregions within the rangelands region

Table 7.1: IBRA Bioregions within the rangelands region (ACRIS, 2001) with the percentage of native vegetation remaining within that region
<http://audit.ea.gov.au/ANRA/vegetation/docs/Native_vegetation/nat_veg-appendix1.cfm>

IBRA Region	% Native vegetation remaining	IBRA Region	% Native vegetation remaining
Arnhem Coast	98	Great Sandy Desert	100
Arnhem Plateau	100	Great Victoria Desert	100
Brigalow Belt North	53	Gulf Country	100
Broken Hill Complex	100	Gulf Fall and Uplands	100
Burt Plain	100	Gulf Plains	100
Cape York Peninsula	100	Hampton	100
Carnarvon	100	Little Sandy Desert	100
Central Arnhem	100	MacDonnell Ranges	99
Central Kimberley	100	Mitchell Grass Downs	97
Central Ranges	100	Mount Isa Inlier	100
Channel Country	100	Mulga Lands	87
Cobar Peneplain	89	Murchison	100
Coolgardie	98	Murray Darling Depression	62
Daly Basin	92	Northern Kimberley	99
Dampierland	99	Nullarbor	100
Darling Riverine Plains	68	Ord Victoria Plain	100
Darwin Coastal	97	Pilbara	100
Davenport Murchison Range	100	Pine Creek	99
Desert Uplands	88	Riverina	52
Einasleigh Uplands	98	Simpson Strzelecki Dunefields	100
Finke	100	Stony Plains	100
Flinders Lofty Block	82	Sturt Palteau	99
Gascoyne	100	Tanami	100
Gawler	100	Tiwi Cobourg	98
Geraldton Sandplains	52	Victoria Bonaparte	100
Gibson Desert	100	Yalgoo	98

8. Appendix 2

8.1. Species attributes and mapping resources

Data sources relating to species life history attributes and vegetation and land class mapping are listed below according to the vegetation types described in Section 3.3.

Note two sources of information with application across vegetation types:

- For vegetation types where they occur in the NT, species response data are now available for all NT plant species through a current NHT project, undertaken through the BFCNT.
- For vegetation mapping refer to the National Land and Water Audit as all the state government documentation has been itemised in the Audit.

1. Tropical eucalypt forests and woodlands (savannas)

Species life history attributes

Completed (or near completed) for the vegetation of Nitmiluk (Edwards et al. 2001), Bradshaw Station (Yates & Russell-Smith 2003), and Alligator Rivers Region (Brennan 1996a,b). (Refer also to NHT project *Developing a regionalised strategic fire management framework for the NT).*

Vegetation and land class mapping resources

The vegetation of the savannas has been mapped at 1:2,000,000 across the region (Fox et al. 2001). The NT vegetation is mapped at 1:1,000,000 (Wilson et al. 1990). More localised surveys by State Government Departments have been undertaken at scales of 1:50,000-100,000 e.g. NT DIPE etc.

2. Melaleuca woodlands

Species life history attributes

Vegetation type attributes are currently being drafted for the vegetation of Cape York Peninsula (Crowley in preparation).

Vegetation and land class mapping

All of this vegetation type lies within the tropical savannas, which has been mapped in its entirety at 1:2,000,000 (Fox et al. 2001). More detailed maps are available within each jurisdiction, at 1: 1,000,000 for Western Australia (Beard & Webb 1974; Beard 1979; Hopkins et al. 1999) and the Northern Territory (Wilson et al. 1990) and at 1:250,000 for Cape York Peninsula in Queensland (Neldner & Clarkson 1995).

3. Tussock grasslands

Species life history attributes

(Not known)

Vegetation and land class mapping

Most of the tussock grasslands of Queensland are mapped at 1:250,000 (Boyland 1984; Neldner 1984; Neldner 1991), with the exception of those in Gulf Plains bioregion, where detailed mapping is currently underway. The most detailed currently available vegetation mapping for this bioregion is the1:2,000,000 map of the tropical savannas (Fox et al 2001). Most of the grasslands of the Northern Territory, and New South Wales have been mapped at 1:1,000,000, and those in South Australia at scales varying from 1:100,000 to 1:2,000,000 depending on the region.

4. Hummock grasslands

Species life history attributes

The database of NT species (refer to NHT project *Developing a regionalised strategic fire management framework for the NT*). Other regional species attribute datasets may contain information on species within the hummock grassland ecosystems.

Vegetation and land class mapping

The National Land and Water Resources Audit's national vegetation compilation provides a small-scale delineation of hummock grassland ecosystems, either as major vegetation types or as a ground layer within other vegetation. Only a few areas of hummock grasslands have been mapped in detailed scales (greater than 1:250,000) as part of land resource surveys of pastoral leases or national parks. The majority of the hummock grassland areas are beyond the pastoral zone and commercial operations and have not been a mapping priority.

The close association of hummock grasslands to aeolian sand landforms provides an opportunity to infer hummock grassland habitats from many geological maps, however the interpretation and collation has not been systematically undertaken. Geologic maps are available at a range of scales, with national coverage at 1:250,000 and many regions at finer scales. A greater challenge is the interpretation required for similar maps in the less extensive but more complex rocky landscapes. The early CSIRO land system mapping programs (during the 1950s and 1960s, generally compiled at 1:1,000,000 scale) and a few land resource surveys provide descriptions and associations between spinifex, landforms and geology that could guide the process. Several smaller regional projects (i.e. CRC LEME regolith mapping) could contribute information to a national compilation.

5. Temperate eucalypt and open woodlands

Species life history attributes

Data are available on fire responses of plant species for NSW (NSW Fire Response Database, Bradstock *et al*. 2004). This database incorporates information from databases in South Australia and Victoria and therefore may be more widely applicable.

Vegetation and land class mapping

Broad scale mapping (e.g. circa 1:1,000,000) is available in NSW, e.g. Beadle 1948, Pickard and Norris 1994 that includes vegetation types along with partial finer scale mapping (e.g. Sivertsen and Metcalfe 1995). Other resources include NSW Soil Conservation Service land system mapping.

6. Acacia forests, woodlands, open woodlands and shrublands

Species life history attributes

As indicated in the vegetation type description, species response data for most Acacia spp. are not readily available.

Vegetation and land class mapping

Refer to the National Land and Water Audit as all the state government documentation has been itemised in the Audit.

7. Chenopod shrubs, samphire, forblands

Species life history attributes

Data are available on fire responses of plant species for NSW (NSW Fire Response Database, Bradstock et al. 2004). This database incorporates information from databases in South Australia and Victoria and therefore may be more widely applicable.

Vegetation and land class mapping

Broad scale mapping (e.g. circa 1:1,000,000) is available in NSW, e.g. Beadle 1948, Pickard and Norris 1994 that includes vegetation types along with partial finer scale mapping (e.g. Fox 1991, Scott 1992). Other resources include NSW Soil Conservation Service land system mapping.

8. Mallee

Species life history attributes

Data are available on fire responses of plant species for NSW (NSW Fire Response Database, Bradstock et al. 2004). This database incorporates information from databases in South Australia and Victoria and therefore may be more widely applicable.

Vegetation and land class mapping

Broad scale mapping (e.g. circa 1:1,000,000) is available in NSW, e.g. Beadle 1948, Pickard and Norris 1994 that includes vegetation types along with partial finer scale mapping (e.g. Fox 1991, Scott 1992, Cohn 1995). Other resources include NSW Soil Conservation Service land system mapping.

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[See also sections describing respective vegetation types]

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