Guiding principles for fire management in the Western Australian rangelands

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Introduction

In February 2014, the Western Australian Rangelands NRM convened a Rangelands Fire Forum in Perth, WA. An outcome of this meeting was to develop fire management guidelines for the WA rangelands. This document provides a broad framework and high level knowledge-based principles to guide fire management in the rangelands. The extent of fire knowledge is variable across the rangelands so application of these guidelines should be in an adaptive management framework so that in addition to structured research programs, we learn by doing.

In this context, the rangelands cover some 2.26 million km^2 (~85%) of WA, a vast area of cultural, social, environmental and economic significance, with industries such as mining, pastoralism and tourism being important to the state and national economy. All stakeholders in the rangelands are concerned about the protection of lives, property, livelihoods, cultural assets and environmental services from the harmful effects of inappropriate fire regimes. Land holders, land managers and bushfire emergency services are also concerned with using planned fire to reduce the bushfire threat to these assets, to enhance ecosystem resilience, to manage pastures and for other economic benefits. In many Indigenous communities, fire is important for hunting, for bush foods, for caring for country, and for other customary responsibilities. It is anticipated that these guiding principles will provide a framework to assist land holders, land managers and bushfire emergency services with the formulation of policies, plans and prescriptions for good fire management in the rangelands. Others may find this document useful as a communication and training resource.

This document includes a brief biophysical description of the WA rangelands and generic fire management principles applicable to most fire-prone regions of the rangelands. Broad Bushfire Regions, based largely on climate and vegetation, are identified and summaries of the fire environment, the likely ‘natural’ or pre-European fire regime (which includes Aboriginal burning), the current fire regime, guiding principles for fire management and identification of critical knowledge gaps are provided for each Region.

Western Australian Rangelands

The following description of the WA rangelands is adapted from the Rangelands NRM website (http://www.rangelandswa.com.au/425/what-are-rangelands).

‘Rangelands’ is a generic term describing the arid and semi-arid regions of WA, although in this context, it also includes the high rainfall region of the north Kimberley. As illustrated by the map in Figure 1, it is essentially all of the state of Western Australia beyond the south-west corner, roughly delineated by the 300 mm rainfall isohyet. Spread across some

19 degrees of latitude and 16 degrees of longitude, the rangelands encompass a great diversity of climates, landforms and vegetation types ranging from wet-dry tropical savannas in the north, spinifex-dominated deserts in the arid interior, acacia and chenopod shrublands and mulga woodlands in the semi-arid interior and eucalypt woodlands and heathlands in the Mediterranean-type climates in the south. It also encompasses a diversity of land tenures and land uses, including mining tenements, pastoral leases, Aboriginal lands, conservation lands and unallocated crown land.

Figure 1: The WA rangelands (courtesy Rangelands NRM)

Bushfire environment

The bushfire environment of the rangelands is as variable as the climate and vegetation, and there is a long association between these factors that pre-dates the arrival of humans by thousands of years. Most landscapes in the rangelands are prone to bushfires at varying intervals and seasons, so can be considered as fire maintained or fire dependent. These include some of the most fire-prone landscapes on Earth, such as the tropical savannas of the north Kimberley, which have the potential to burn every year.

Today, the scale of bushfires in the rangelands, especially in the tropical savannas and the spinifex deserts, rank among the largest in the world. It is not uncommon for bushfires in the spinifex deserts to burn several hundred thousand hectares over a couple of weeks. Each year in the tropical savannas, bushfires burn hundreds of thousands of hectares, mostly in the mid to late dry season. Similarly, very large summer bushfires occur infrequently in the woodlands, shrublands and grasslands of the southern rangelands.

Because these large bushfires mostly occur in remote, sparsely populated areas, they are generally not of great concern to the broader WA community and rarely attract media attention. However, where they occur on pastoral lands, they can damage infrastructure, injure or kill stock and impact on pasture availability. Where they occur in highly visited areas such as national parks and other amenity and recreation areas, they can threaten visitors to these areas as well as infrastructure. Bushfires also threaten homes and infrastructure of remote communities including Aboriginal communities and mining camps. However, the ecological and environmental damage of these bushfires, while not well understood, is likely significant. There is growing evidence that across the rangelands, large, intense bushfires are implicated in the recent decline of some plant and animal species, are a significant source of greenhouse gas emissions and degrade populations of long-lived woody plants such as mulga (*Acacia aneura*), which serve important ecological, environmental and cultural functions.

However, there are some ecosystems and vegetation types in the rangelands that are not prone to fire due to the sparse nature of vegetation (fuel), natural barriers to fire spread or moisture regimes that make them non-flammable for long periods. These ecosystems are therefore either fire independent or fire sensitive and can be readily, and in some cases, irreversibly damaged by fire, especially in combination with invasive weeds and excessive grazing.

As with all fire-prone regions, fire regimes can be helpful or harmful to communities and to the environment. Attempted fire exclusion and suppression alone, as well as being potentially environmentally harmful, dangerous and costly, will fail to mitigate the damaging effects of bushfires. Fire suppression, in combination with appropriate levels of prescribed burning and other fuel management strategies such as grazing or slashing to manage the fuel hazard is most likely to succeed in mitigating the bushfire threat and in meeting stakeholder aspirations. Regardless of the level of effort in bushfire threat mitigation, there will always be some level of residual risk – good fire management aims to minimise residual risk.

These guiding principles are designed to assist with decision making about the most appropriate fire regimes likely to afford a level of bushfire mitigation, maintain and protect native wildlife and resources, maintain ecosystem health and reduce greenhouse gas emissions. Because the guiding principles apply to the vast and diverse area of the rangelands, they are necessarily high level. In addition to guiding principles that are broadly applicable to all fire prone ecosystems (generic guiding principles) the rangelands are classified into six Bushfire Regions, or large areas with broadly similar fire environments (climate, vegetation/fuels and fire response) for which specific guiding principles are also developed.

The Rangelands NRM has identified and mapped seven sub-regions, which are based on the Interim Biogeographic Regionalisation of Australia (IBRAs or bioregions) (Figure 1). Bioregions are large, geographically distinct areas of land with broadly common characteristics such as geology, climate, landforms and wildlife so lend themselves to a broad classification of bushfire regions. Bushfires 'read' the vegetation as fuel, so physical attributes of the vegetation (structure and biomass) characterise it as fuel, not species *per se* (although structure and floristic assemblage are sometimes linked).

Notwithstanding the limitations of land system/vegetation mapping, the Rangelands NRM sub-regions form a useful basis for classifying Bushfire Regions (Figure 2). The proposed six Bushfire Regions and associated bioregions (parentheses) are as follows;

1. North Kimberley (North Kimberley, Central Kimberley, Victoria Bonaparte bioregions)
2. West Kimberley (Dampierland bioregion)

3. Desert (Pilbara, Great Sandy Desert, Little Sandy Desert, Gibson Desert, Great Victoria Desert, Ord Victoria Plain, Tanami bioregions)
4. Gascoyne-Murchison (Carnarvon, Gascoyne bioregions Murchison, Yalgoo bioregions)
5. Goldfields (Coolgardie bioregion)
6. Nullarbor (Nullarbor bioregion)

The amalgamation of the Pilbara and various northern and southern desert bioregions to form a single Desert Bushfire Region is justifiable on the grounds that while there are soil and landform differences, and a north-south climate gradient (north predominantly summer rainfall, south predominantly winter rainfall), spinifex (*Triodia spp*.) grasslands form the dominant fuel and the region is arid, experiencing unreliable rainfall and long periods of hot dry weather.

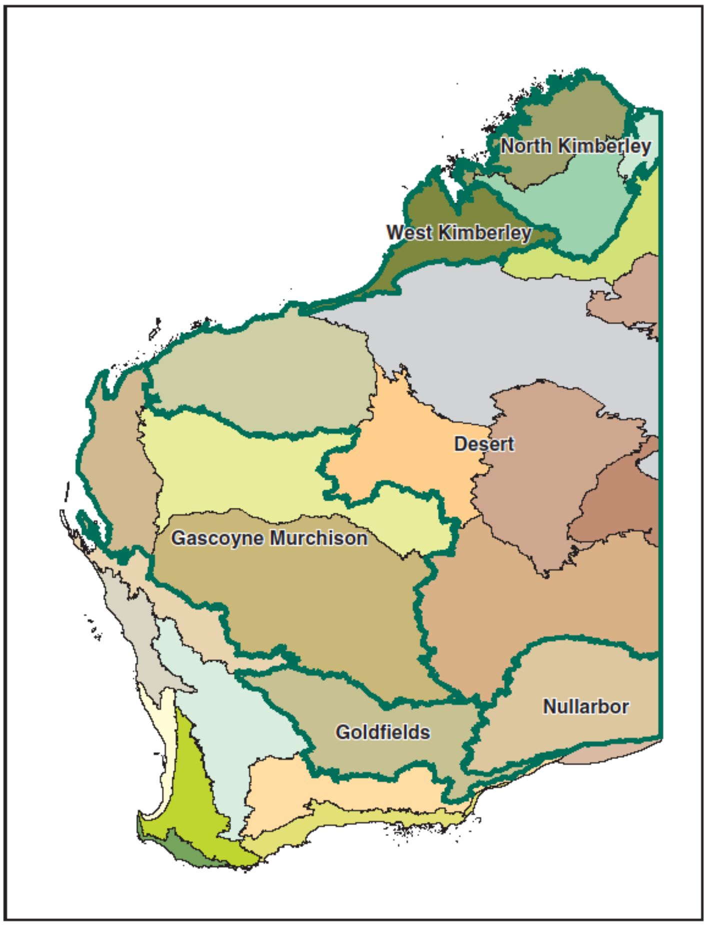

Figure 2: Bushfire Regions in the WA rangelands

Generic guiding principles in bushfire-prone landscapes

1. There is a long and continuing association between fire, climate (especially rainfall), vegetation and people in the WA rangelands. Therefore, it is critical to maintain people in these landscapes if fire is to be appropriately managed.
2. Fire is an environmental factor that has and will continue to influence the nature of fire-prone landscapes in the rangelands, so fire management (by people) is an integral part of sustainable land management.
3. Fire management is necessary for two primary reasons; a) to reduce the risk of the harmful effects of unplanned bushfires on life, property, livelihoods, cultural and environmental values, and b) to protect and maintain healthy ecosystems to deliver

conservation and cultural outcomes, environmental services and resource production, including pasture and bush foods.
4. Bushfires can be harmful to people and to community values and assets so risk management must be based on a systematic and structured approach to identifying and managing the hazard and the potential consequences.
5. Native plants and animals (wildlife) vary in their adaptations to and dependence on fire and no single fire regime benefits all wildlife.
6. All available knowledge including Aboriginal knowledge, species vital attributes and life histories should underpin fire management regimes including implementing sustainable fire regimes (fire season, interval, size and patchiness).
7. The impacts, damage potential, greenhouse gas emissions and suppression difficulty of bushfires are directly proportional to the intensity and size of the fire.
8. The rate at which plants and animals recover following fire will depend on the severity (size and intensity) of the fire and on subsequent rainfall.
9. Following fire, other environmental factors such as random weather events and introduced plants and animals can drive ecosystems towards a new transient state with respect to species composition and structure.
10. Fire management should be both precautionary and adaptive (learning by doing), considering ecological and risk mitigation objectives in order to optimise outcomes.
11. Within ecological limits, fire diversity (season, intensity, and interval) is likely to benefit biodiversity at the landscape scale and the local scale.
12. At the landscape scale, a fine scale mosaic of patches of vegetation at different growth stages (seral stages), or times since fire, will provide diverse habitat opportunities and will facilitate post-fire recovery and recolonisation of recently burnt patches. Long unburnt vegetation forms an important part of the mosaic.
13. The scale or grain size of the mosaic should a) enable natal dispersal, b) optimize boundary habitat (boundary between two or more seral stages), and c) optimize connectivity (ability of key species to migrate between seral stages).
14. Consultation and partnerships among stakeholders is an effective way of managing fire for mutual benefit.
15. Fire management should be planned and implemented in an adaptive management framework. Use of tools including remote sensing and aircraft, will be essential for planning and implementing fire use and for mapping and monitoring fire history.
16. As part of an adaptive management framework, monitoring the effects of fire management on wildlife should focus on threatened and fire sensitive species and communities, and on culturally significant species.

In addition to the above generic principles, guiding principles are developed for each Bushfire Region. There is some repetition of principles from one region to another, particularly where there is insufficient knowledge, so broad fire ecology principles may apply across multiple Bushfire Regions.

North Kimberley Bushfire Region

Fire Environment

The climate of this region is wet-dry tropical, with annual rainfall in the range 900-1200 mm. Predominant vegetation is eucalypt forests and woodlands with a grassy understorey. In drier parts of the region or on stony soils, spinifex (*Triodia spp*.) may form the dominant fuel. Embedded in these landscapes are a variety of other vegetation associations including fire sensitive ecosystems such as monsoon vine thickets, rainforests, and fire sensitive species such as *Callitris*. Grasses and herbs accumulate during the warm months of the wet season (about November to March) and quickly cure during the dry season (about April to October), resulting in frequent, extensive fires. In most years, up to 80% of the region is burnt each year. Fires are lit by people and lightning, especially in the mid to late dry season.

Natural fire regime

Aboriginal people lit fires for a myriad of reasons, primarily in the early dry season to take advantage of moisture / flammability differentials that existed across the landscape at this time. This resulted in better control of fires, which were mostly low intensity and patchy. Fire sensitive communities and species in less flammable (wetter) parts of the landscape (refugia) were able to escape being frequently burnt, or were able to survive low intensity fires at this time of year. Fires also burnt during the dry season with the coincidence of lightning storms and dry vegetation, but the scale and intensity of these fires was probably constrained by earlier burning and rain associated with the storms.

Current fire regime

Most of the region is burnt annually or biennially (savannas), or every 3-5 years (spinifex) by mid to late dry season fires. Dry grass across the landscape and often severe fire weather at this time results in large, relatively intense fires that can burn the entire landscape leaving few unburnt patches. In addition to impacting infrastructure, pastoral activities and other cultural and community assets, this regime is harmful to fire sensitive plant communities, is implicated in the decline of some species of plants and animals, and results in elevated greenhouse gas emissions.

Guiding principles

- Climate and vegetation ensure that fires will occur every year in this region.
- The natural fire regime is likely more beneficial to biodiversity and the environment than the current regime of predominantly large and intense mid to late dry season fires. The natural fire regime is likely to allow fire refugia to function as such, improving protection to fire sensitive communities and species. A regime dominated by large and intense late dry season fires threatens fire sensitive communities and species as well as cultural and economic assets.
- Fire management should aim to increase the area burnt by early dry season fires and decrease the area burnt by mid to late dry season fires. It should also aim to reduce the total area burnt per annum.
- Relatively long unburnt patches are important habitat elements for some animal species.

Critical Knowledge gaps

- The optimal landscape scale mosaic of fire intervals to benefit wildlife, optimise ecosystem productivity and improve ecosystem resilience.
- Interactions between fire regime and other threatening process such as introduced predators and weeds.

West Kimberley Bushfire Region

Fire environment

This region experiences a hot semi-arid to tropical monsoonal climate with distinctive wet and dry seasons analogous to the North Kimberley Bushfire Region but a lower rainfall. The region has a variety of vegetation / fuel types including areas of spinifex grasslands and savannas but is characterised by a predominance of pindan or acacia shrubland with scattered eucalypts. The presence of annual sorghum promotes an annual or biennial fire interval.

Natural fire regime

Most likely a regime of frequent patch-burning in the early dry season by Aboriginal people and lightning–caused fires later in the dry season. Early dry season fires were low intensity, relatively small and patchy, and restricted the size and intensity of late dry season fires.

Current fire regime

The current fire regime is similar to that experienced by the North Kimberley Bushfire Region, being characterised by frequent large and intense bushfires in the mid to late dry season (August-December). These fires homogenise / simplify the vegetation growth stages and structures over large areas, with mid-storey vegetation particularly at risk. They also threaten fire sensitive ecosystems such as monsoon vine thickets and mound springs.

Guiding principles

- Reduce the area burnt by late dry season fires by increasing the proportion of the area burnt in the early dry season and installing strategic fuel reduced buffers when sorghum is partially cured.
- Progressively reduce the size of late dry season fires by burning in the early dry season to establish a coarse-grain mosaic of burnt patches and by installing a strategic network of low fuel buffers.
- Use prescribed fire mosaics to increase the level of protection to fire sensitive ecosystems such as monsoon vine thickets and mound springs.

Critical knowledge gaps

- Determine tolerable fire intervals to maintain ecosystem resilience.
- Determine importance of different growth stages / vegetation / fuel ages to biodiversity including long unburnt vegetation.
- Appropriate fire mosaics (temporal and spatial scales) for resilient ecosystems, including protection of fire sensitive communities.
- Better understanding by fire and land management agencies of tenure and land stewardship with respect to Traditional Owners.

Desert Bushfire Region

Fire environment

This region experiences an arid (desert) climate with low (<300 mm per annum average), unreliable rainfall. In the north, rainfall mostly falls in summer grading to predominantly winter rainfall in the south. Spinifex (*Triodia spp.*) grasslands on a variety of substrates and landforms (sand plains, dunefields, stony plains, stony hills) form the dominant ground cover and fuel, and is the common characteristic of this region. A variety of scattered shrubs, low trees and mallees often grow in association with spinifex. The region experiences long periods of hot, dry and windy weather, which combined with expanses of flammable spinifex grasslands, results in extensive bushfires at frequencies of 10-20 years. Vegetation growth, hence fuel accumulation, is largely driven by rainfall and periods of above average rainfall usually culminates in large, intense bushfires started by lightning or people.

Natural fire regime

Aboriginal people used, and in some areas, continue to use fire for a variety of reasons, but primarily to acquire food. In the Western Desert part of the region, widespread frequent burning over thousands of years resulted in a fire-stable landscape comprising a mosaic of habitats and patches of vegetation at different growth stages, or times since fire with most of the landscape in the early to medium post-fire state. Based on available knowledge, in areas frequented by Aboriginal people, the mean burnt patch size was <100 ha, with fires rarely exceeding 5,000 ha. While fires were lit all year round, most burning was done in the cooler time of the year. Lightning-caused fires occurred in the hotter times but regular burning by Aboriginal people and subsequent lack of fuel continuity prevented most fires from growing to a large size. The minimum fire return interval in spinifex grasslands varies from 7 - 12 years, depending on rainfall and site conditions.

Current fire regime

With the departure of Aboriginal people from a traditional lifestyle, including the cessation of burning throughout most of the region, the fire regime has altered significantly. Whereas the natural fire regime was largely driven by Aboriginal burning and rainfall, the current regime is driven by rainfall and lightning. In areas remote from Aboriginal communities and pastoral leases, the fire regime is generally one of frequent (~10-20 year intervals) very large, intense hot season wildfires. The mean fire size has increased by many orders of magnitude and wildfires in excess of 100,000 ha are common throughout the region. Little is known about the ecological effects of the current fire regime, but it has been implicated in the decline and local extinction of some ground nesting birds and some mammal species, and the decline of some fire sensitive plant species such as mulga (*Acacia aneura* and its close relatives) and Cypress (*Callitris* spp.). The current fire regime has also resulted in an increase in greenhouse gas emissions and a decrease in carbon biosequestration.

Fire regimes near Aboriginal communities and access tracks are similar to the ‘natural’ fire regime described above. Fire regimes on pastoral leases and conservation lands is a mix of managed and unmanaged fires.

Guiding principles

- Rainfall is the primary driver of the rate of fuel accumulation and large wildfires usually follow seasons of above average rainfall.
- The response of species and communities to fire will be influenced by the subsequent rainfall and by the scale and patchiness of fire.
- Large, intense hot season fires are harmful to the environment, to biodiversity and to cultural integrity.
- A fine grain mosaic of patches of vegetation representing a range of growth (post-fire) stages, including patches of long unburnt vegetation, will benefit biodiversity by providing diverse habitats. It will also buffer these landscapes from large wildfires following periods of above average rainfall.
- Cool season fires, or burning soon after rain when fuels are moist, is likely to result in smaller, low intensity patchy fires that are less likely to damage fire sensitive species and communities such as mulga. Strategic low fuel buffers greatly assist with prescribed burning and wildfire control.
- Where spinifex grasslands have been invaded by weeds such as buffel grass, which is capable of adversely altering the frequency and intensity of fire, prescribed fire should be used cautiously and strategically to disrupt the run of major wildfires.

Critical knowledge gaps

- For the variety of IBRAs and ecosystems in the region:
  - tolerable fire intervals,

- ‘ideal’ (spatial and temporal) fire-induced landscape mosaics of vegetation growth stages to benefit biodiversity, buffer impacts of large fires and reduce greenhouse gas emissions.
- buffel grass – it’s distribution, dispersal and effects on ecosystem health.
- human population trends and demography.
- improved modelling of climate change.

Gascoyne-Murchison Bushfire Region

Fire environment

This region experiences an arid climate with cool winters and hot summers. The predominantly winter rainfall is unreliable with the mean annual rainfall being 200-250 mm. Vegetation is predominantly low open mulga woodlands, eucalypt woodlands, sandplain heath/shrublands, acacia shrublands with spinifex grasslands occurring more frequently in the north-east. Due to the sparse vegetation, especially ground cover, mulga woodlands and acacia shrublands are mostly non-flammable. However, following several years of well above average summer and winter rainfall, coupled with reduced grazing pressure, an understorey of flammable annual grasses and herbs can develop, resulting in fast spreading but low intensity bushfires.

Natural fire regime

The natural fire regime is unknown.

Current fire regime

The frequency of significant bushfire events in mulga woodlands, eucalypt woodlands and acacia shrublands is very low (50-100 years), and in the more flammable vegetation types (spinifex grasslands, sandplain shrublands), is in the range 10-20 years. Much of the region’s vegetation is non-flammable due to sparse vegetation cover and there is evidence that these ecosystems (except spinifex grasslands and sandplain shrublands) are fire sensitive and fire independent. Reduced grazing by stock since the 1990s may increase the frequency of bushfires in this region.

Guiding principles

- For the flammable vegetation types in this region, see ‘Guiding Principles’ for the Desert Bushfire Region (spinifex sandplains) and the Goldfields Bushfire Region (sandplain shrublands and eucalypt woodlands).
- Exclude fire from mulga woodlands and acacia shrublands (fire sensitive vegetation), and where feasible, suppress fires in these vegetation types.

Critical knowledge gaps

Most of the vegetation types in this region are non-flammable or burn at long intervals, are fire sensitive (readily killed by fire) and are fire independent (fire is not part of their ecology). Further research is needed on the role of fire in maintaining biodiversity and productivity of flammable vegetation types.

Goldfields Bushfire Region

Fire Environment

The climate of the region is arid to semi-arid with hot dry summers and mild winters. Rainfall in the west of the region is mostly in the winter months whereas in the east it is non-seasonal. Long periods of extreme fire weather are common in the dry summer months.

Vegetation comprises a rich mosaic of eucalypt woodlands on low hills and heavy soils interspersed with dense shrublands on yellow sand plains. These broad, often interlinked vegetation types have contrasting fuel properties, hence fire regime potentials and responses to fire. The fuel in the eucalypt woodlands comprises sparse, usually discontinuous leaf litter and a low open understory of small shrubs, making these fuels of low flammability. In contrast, the often dense shrublands become a highly flammable fuel, especially under dry, windy conditions. Fire intervals in the woodlands can be many decades, even centuries, whereas much shorter fire intervals are possible in the more flammable shrublands.

Natural fire regime

There is limited evidence that Aboriginal people may have burnt the more flammable shrublands under mild weather conditions resulting in a mosaic of shrubland vegetation at different growth stages. This regime may have increased protection to the more fire sensitive woodlands, which appear to have burnt at much longer intervals.

Current fire regime

Bushfires in this region are mostly started by lightning. While infrequent, under extreme weather conditions they can be large, intense and burn all vegetation types including woodlands.

Guiding principles

- The dominant vegetation types display contrasting fuel and flammability properties; eucalypt woodlands are of low flammability but adjoining shrublands on sandplains are highly flammable when mature.
- Eucalypt woodlands are fire sensitive (readily killed by fire) and are most likely fire independent (do not require fire for their persistence) so should be protected from large, intense bushfires.
- Shrublands are well adapted to fire at intervals of a few decades and recover more quickly than woodlands.
- Extensive salt lake systems can disrupt the spread of fires allowing stands of eucalypt woodland to avoid fire for long periods in these fire ‘shadows’.
- Fire management should aim to reduce the size and intensity of bushfires in these landscapes by burning flammable fuels such as shrublands under cool conditions to reduce the likelihood of fire spreading to woodlands. The installment of strategic low fuel buffers will assist with prescribed burning and with wildfire control.
- Due to the contrasting fuels, a flammability differential exists between woodlands and shrublands, so it may be possible to burn shrublands under mild weather conditions when woodlands will not burn.

Critical knowledge gaps

Formal knowledge of fire behaviour and ecology is limited to a few vegetation communities and fire history case studies. Fire knowledge of Ngadju traditional owners has been recently documented. Priorities for future research include:

- Better understanding the drivers of periodic very large fires.
- Describing and interpreting fire response of plant communities, particularly sandplain shrublands.
- Documenting fire history and regeneration processes in multi-aged eucalypt woodlands.

- Optimal scale of fire mosaics in maintaining ecosystem resilience and buffering landscapes against harmful effects of large intense fires.
- Fire behaviour in shrublands.

Nullarbor Bushfire Region

Fire Environment

The climate of this region is arid to semi-arid; mean annual rainfall is ~200 mm, but is highly variable. Most rainfall is in winter but remnants of tropical cyclones can bring significant summer rainfall. Winters are cool to cold and summers are hot. Vegetation of the region is predominantly non-flammable, fire sensitive chenopod (bluebush and saltbush species), sometimes with a scattered overstorey of myall or mulga. Low open woodlands occur in the in the northern and western parts of the region. Perennial grasses are common where fires or grazing have removed the chenopod vegetation, which only burns if there is an adequate amount of dry grass and herbs. Typical of other arid and semi-arid regions, bushfires are infrequent and usually follow periods of above average rainfall. Bushfires in this region can cause significant and irreversible or long-term changes in the vegetation, with chenopod shrubs being replaced by perennial grasses.

Natural fire regime

Unknown – but fire was probably absent or rare in chenopod shrublands, which are fire sensitive and fire independent in the absence of invasive grasses and herbs.

Current fire regime

Changes to the composition and structure of chenopod vegetation resulting in invasion by flammable grasses and herbs has resulted in very large and damaging summer bushfires, especially following above average rainfall.

Guiding principles

- Chenopod shrublands are harmed by fire and in the absence of invasive grasses, weeds and herbs, are not flammable.
- Disturbances such as fire and grazing can encourage the invasion of grasses, herbs and weeds which make chenopod shrublands flammable, especially following above average rainfall.
- Fire and land management should aim to exclude fire or reduce the risk of large damaging fires. This may mean treating fuels in more flammable parts of the landscape including by prescribed burning or by mechanical means, and the installation of strategic low fuel buffers.

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Further reading:
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