A FIRE MANAGEMENT PLAN FOR THE COONGAN BILBY LAND MANAGEMENT AREA (LMA): 2019-2022

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Executive summary

This fire management plan for the period 2019-2022, is part of a Greater Bilby Offset Project funded by Roy Hill Iron Ore, to enhance the likelihood of persistence of at least one wild meta-population of the greater bilby (*Macrotis lagotis*) on the Coongan pastoral lease in the east Pilbara. This will be achieved by using prescribed fire to improve and maintain habitat, and by mitigating the risk of predation by introduced predators. The Offset Project is a collaboration involving Roy Hill Iron Ore, the Warralong Community, Greening Australia, Outback Beef (Yarrie/Coongan pastoral leaseholder) and the Department of Biodiversity, Conservation and Attractions (DBCA). Building the capacity of the Warralong Community to engage in land management, including fire management, is a key outcome of this project. The purpose of this plan is to provide guidance to managing fire for bilby conservation as well as for economic, cultural and environmental outcomes. To this end, the plan includes a synthesis of the science and information that underpins the objectives, strategies and tactics outlined in the plan.

Key fire management strategies include buffer burning of the perimeter of the ~10,000 ha Coongan Bilby Land Management Area (hereafter LMA) using trained fire crews from the Warralong Community, and ground-based (hand) patch-burning under prescribed conditions. These strategies aim to a) prevent large fires (planned or unplanned) entering or leaving the project area and b) create and maintain a fine-grain mosaic of vegetation at different seral (post-fire) stages, providing suitable habitat and protection for bilbies and other terrestrial native fauna such as mulgara (*Dasycercus* sp.). The plan also promotes a patch-burn strategy for the landscapes surrounding the project area. Being on the Coongan pastoral lease, it is imperative that fire operations outlined in this plan are endorsed by, and are integrated with, management aspirations on the pastoral lease. The plan also addresses training and resourcing requirements for its implementation, and metrics in relation to the desired landscape fire patterns for bilby conservation. Constructive consultation and collaboration with a variety of key stakeholders will be important for the successful implementation of the plan.

Contents

1. Introduction

1.1. Planning area and context

This fire management plan is part of a Greater Bilby Offset Project funded by Roy Hill Iron Ore to enhance the likelihood of persistence of at least one meta-population of the greater bilby (*Macrotis lagotis*) on the Coongan pastoral lease near Warralong in the east Pilbara by improving and maintaining habitat and by mitigating the risk of predation by introduced predators (Roy Hill 2018). The Offset Project is a collaboration involving Roy Hill Iron Ore, the Warralong Community, Greening Australia, Outback Beef (Yarrie/Coongan pastoral leaseholder) and the Department of Biodiversity, Conservation and Attractions (DBCA). Building the capacity of the Warralong Community to engage in land management, including fire management, is a key outcome of this Offset Project (Roy Hill 2018). The purpose of this plan is to provide guidance to managing fire for bilby conservation as well as for economic, cultural and environmental outcomes. To this end, the plan includes a synthesis of the science and information that supports the objectives, strategies and tactics described in the plan.

The ~10,000 ha Coongan Bilby Land Management Area (LMA) lies within the Coongan pastoral lease in the Pilbara bioregion (IBRA), Chichester subregion (Figure 1). The four year plan (2019-2022) focuses on the LMA, however the landscape scale nature of fire, and the mobility of bilbies, requires that the plan considers and is integrated with fire and other management activities in the greater landscape of the Coongan pastoral lease. Therefore, the plan will need to be supported by the Coongan leaseholder. The bilbies could move north onto the De Grey lease, so the leaseholder for the De Grey lease should also be consulted about the plan.

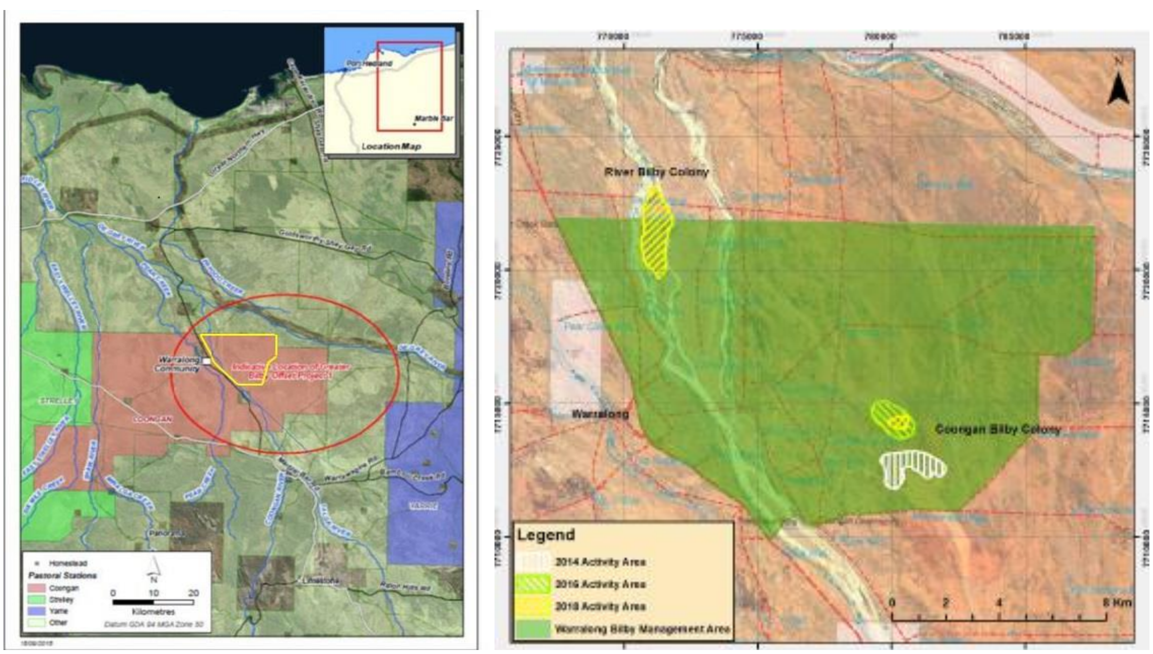

Figure 1: Indicative location of the Coongan Bilby Land Management Area (LMA) (yellow) on Coongan station, and locations of extant bilby meta-populations.

1.2 Background information and supporting science

Highly flammable vegetation and long periods of hot, dry weather have ensured that hummock grassland (spinifex) ecosystems have had a long association with fire (Jones 1969; Kimber 1983, Allen and Griffin 1986, Allen and Southgate 2002; Burrows *et al. 2006*). These ecosystems are not only flammable, but they are fire maintained, with plants and animals displaying a variety of physical and behavioural traits that enable them to persist with, and in many cases, depend upon a range of fire regimes. Fires are caused by lightning and people. With the arrival of Aborigines some 40,000 years ago (Jones 1969; Flood 1983), people became the greatest source of ignitions (see Plate 1). In the Western Desert, Aboriginal people have, and in some places, continue to use fire for a variety of purposes, but mostly as a tool to acquire food and to “clean up country” (Burrows *et al*. 2006).

There is evidence that fire regimes in many spinifex-dominated landscapes changed when Aboriginal people were displaced from their land and discontinued traditional burning practices (Burrows and Christensen 1990; Burrows *et al*. 2006). In a relatively short time, the fire patterns changed from a fine-grain mosaic comprising numerous mostly small burnt patches at different times since fire (seral states or fuel ages), to a coarse grain mosaic of fewer seral states. The grain size of the mosaic, or the fire size, increased by several orders of magnitude following the cessation of Aboriginal burning as large, intense spring-summer bushfires dominated the fire regime. This pattern is consistent with that observed in other flammable landscapes around the world following a reduction in fire frequency – usually due to the departure of people, the abandonment of traditional management practices that shaped these ecosystems, or fire suppression policies. In almost all situations where this has occurred, there are fewer fires and the fire interval is longer, but the fires are larger, more intense and more damaging.

This pattern may have been modified on pastoral leases, where pastoralists re-introduced fire to protect assets from bushfire and to promote forage for stock, or where grazing reduced fuel loads and fire severity. For much of the spinifex lands though, the fine scale habitat mosaic maintained by traditional Aboriginal burning over millennia (Plate 1; Burrows *et al.* 2006) has been obliterated and replaced with fewer, much larger and more intense fires.

On some soil types, especially on river flood plains, buffel grass (*Cenchrus ciliaris*), an introduced perennial grass, has displaced spinifex and other native plants, sometimes forming almost pure, dense meadows. Buffel grass, which is an aggressive coloniser on some sites, is able to resprout following fire and can significantly alter the natural fire regime by increasing the frequency and severity of fire, which, in some cases, has resulted in the localised decline of native wildlife.

Plate 1: Traditional Martu/Pintupi patch-burning in the Gibson Desert south west of Lake McKay. Photo: RAAF 1953.

Altered fire regimes have been implicated in the decline of arid zone fauna over the last 80 years or so, with medium-size mammals and some bird species most severely affected (Saxon 1984; Burbidge and McKenzie 1989). While predation by introduced predators is most likely the primary cause of declines, this will have been exacerbated by highly altered fire regimes. Large, intense fires simplify habitat structure and diversity and temporarily remove vegetation cover over large areas, exposing native terrestrial fauna to predation (Burbidge and McKenzie 1989; Letnic 2005).

Because of their somewhat ‘nomadic’ and mostly solitary lifestyle, their omnivorous diet, their relatively larger adult size and their use of a network of protective burrows, bilbies are less vulnerable to the combined effects of altered fire regime and predation by introduced predators (cats, wild dogs and foxes) than most other arid zone medium size mammals. Nonetheless, there is mounting evidence that bilby populations in the Pilbara and the Western Desert have been adversely impacted by large hot wildfires that predispose them to predation, and there is observational evidence that the Pilbara bilby population is in decline (Martin Dziminski pers. comm.). Good fire management to maintain habitat quality, and introduced predator control (foxes, feral cats and wild dogs), are the key to arresting and reversing this decline and increasing the resilience of bilby populations.

As has been the case for the past ~40,000 years, people are integral to fire management in these landscapes and today fire management is integral to ecosystem management, biodiversity conservation and pastoralism. Managing fire for the conservation of biodiversity *per se*, is a laudable but nebulous objective. Fire is one of a number of environmental factors acting alone or together with other factors that influences biodiversity and ecosystem condition. While fire can kill and injure plants and animals, it also stimulates plant regeneration and rejuvenates ecosystem processes such as nutrient cycling. Fire acts on ecosystems and species primarily through its action on the vegetation, or the habitat, at a variety of temporal and spatial scales. At both landscape and patch scales, fire, together with rainfall, alters the structure, composition and biomass of vegetation in space and time.

Vegetation is important in its own right and plants are also the primary producers (first trophic level) in terrestrial ecosystems, providing food and shelter (habitat) for other organisms. Vegetation provides the energy to drive ecosystems and to drive fire. For these reasons, the conceptual approach taken by this plan is to focus on the role of fire in managing the vegetation. Good fire management will mitigate large damaging bushfires and maintain a variety of seral (post-fire) states, hence diverse habitats, at appropriate scales thereby benefitting biodiversity, the environment and pastoralism.

2. The fire environment

2.1 Climate and fire weather

The climate of the Chichester subregion is classified as ‘semi-desert-tropical’, with an average annual rainfall ranging from 300 to 350 mm across the region (Kendrick and McKenzie 2001; BoM climate online). Annual rainfall is variable and mostly falls in summer (Figure 2) from thunderstorms, cyclones and rain-bearing depressions. Because of the high evaporation rates, light summer rainfall can have an ephemeral effect on fuel moisture content. Summers are hot with maximum temperatures often exceeding 40°C (Figure 2) and minimum relative humidities (RH) <25%. Winters are mild with mean monthly minima in the range 11-13°C.

Once spinifex fuels are dry enough to sustain ignition, wind speed is the most important weather variable influencing fire behaviour (Burrows *et al*. 2014). Seasonal wind roses for Telfer are shown in Appendix 1. Winds are predominantly E and SE during the day in most seasons except in the afternoons in spring when wind directions are variable with a northerly bias. Wind speed, temperature and relative humidity (RH) vary seasonally and diurnally. Diurnal changes of temperature and RH are reasonably predictable, but wind speed is less so. Temperature increases from sunrise, peaking about mid-afternoon, then decreases overnight reaching a minimum just before sunrise – the RH trend is the reverse of this.

As part of understanding the fire weather, it is important to understand diurnal wind speed patterns, which, together with other weather and fuel variables, can be used to control fire behaviour and burn patch sizes to some extent. The BoM’s weather forecasting products such as MetEye (http://www.bom.gov.au/australia/meteye/) provide valuable information for assessing fire danger rating and potential fire behaviour, and for planning and implementing prescribed burns such as buffer burning and patch-burning described in this plan.

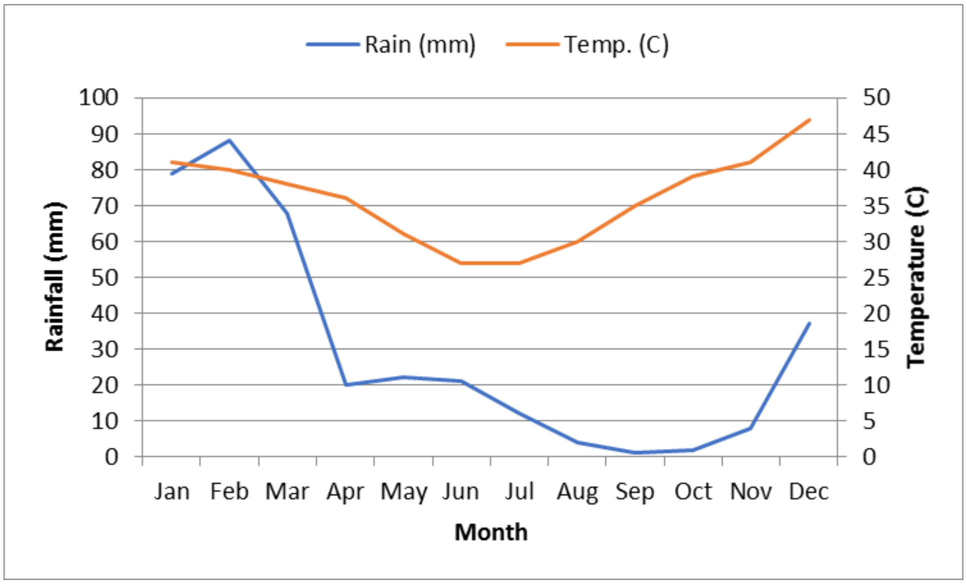

Figure 2: Mean monthly rainfall for Yarrie (1898-2018) and maximum temperatures for Marble Bar (2001-2018) (source: BoM climate on line).

2.2 Vegetation and fuel

The Chichester subregion comprises undulating Archaean granite, basalt plains and areas of basalt ranges. The plains comprise a predominantly Acacia shrub steppe over spinifex (mostly *Triodia wiseana* or *T. basedowii*). When reproductively mature, some 5-7 years post-fire, spinifex cover is generally 35-45% with the cover of a variety of other trees and woody shrubs usually <10%. Soft grasses and short-lived herbs (fire ephemerals) can proliferate in the early seral (post-fire) stages, especially following rain. While the spinifex-dominated landsystems (Figures 3 and 4) could be further classified according to plant species assemblages and overstorey characteristics (if present), their fire-proneness and fire behaviour characteristics (or 'pyrobotany'), are similar because of the dominance of spinifex. That is, fire interprets the landscape according to weather, topography and fuel characteristics rather than species composition *per se*. So pyrobotanically, the spinifex-dominated landsystems are relatively homogenous notwithstanding variation associated with seral state (fuel age) and extent of invasion by buffel grass. It is logical to assume that historical fire regimes, fire response patterns and fire ecology within these spinifex-dominated, flammable landsystems will also be similar, despite some variability in species assemblages. Based on this assumption, and for the purpose of this plan, landsystems dominated by spinifex will be treated as a single 'fire ecosystem'.

Descriptions of spinifex as a fuel are provided by Burrows *et al.* (1991) and Burrows *et al*. (2014) so will not be presented in detail here. Briefly, the spinifex plant is highly flammable due to its physical structure, and in the case of resinous species, its chemical composition. Burrows *et al*. (1991) have described it as an "almost perfect" bushfire fuel.

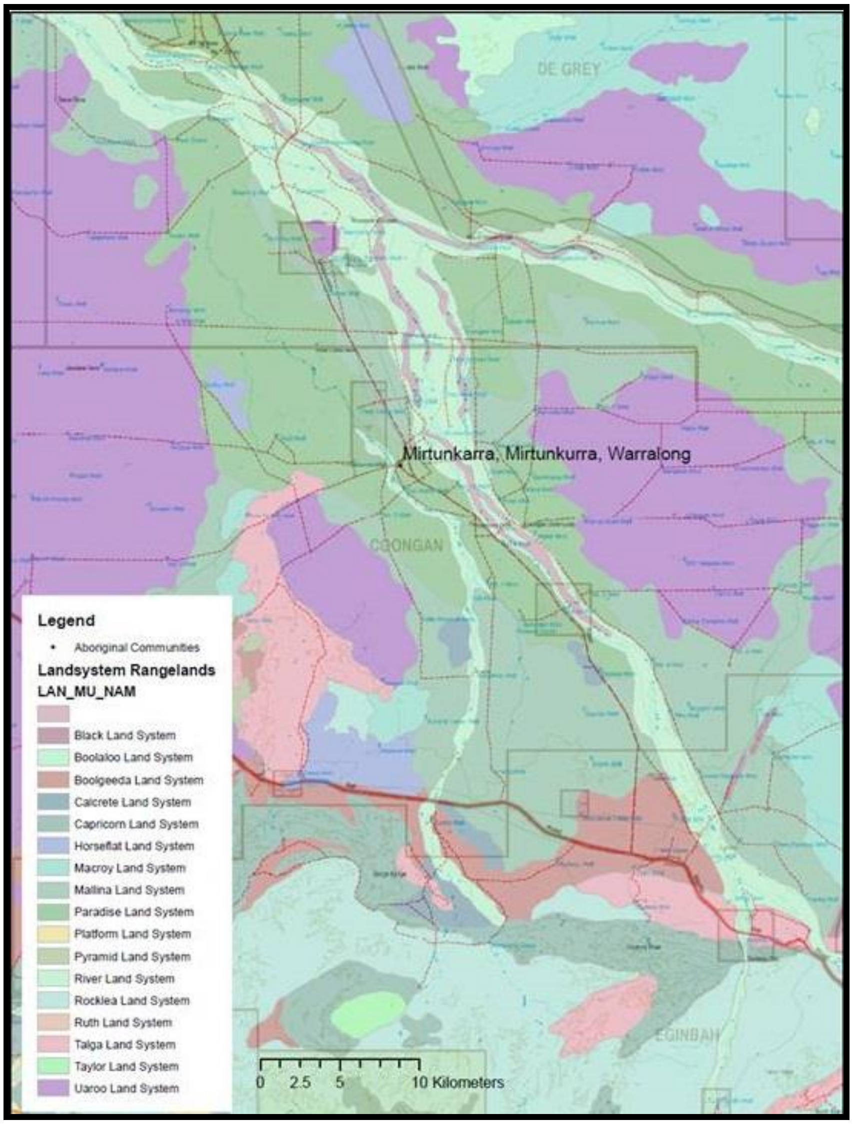

Figure 3: Coongan and surrounding landsystems. Dominant landsystems for the LMA are Uaroo, Mallina, Paradise and River Land (see Table 1 for descriptions).

Landsystem (Figure 3)	Description
Uaroo	Sandy or pebbly plains supporting soft and hard hummock (spinifex) grasslands with scattered Acacia shrubs.
Mallina	Sandy surface alluvial plains supporting soft and hard spinifex grasslands and tussock grass.
Paradise	Alluvial plains supporting soft spinifex grasslands and tussock grass.
River land	Seasonal flood plains supporting tall shrublands or woodlands of Acacia and fringing communities of Eucalyptus sometimes with tussock grass or spinifex. Susceptible to invasion be buffel grass.

Table 1: Description of dominant landsystems in the LMA (see Figure 3).

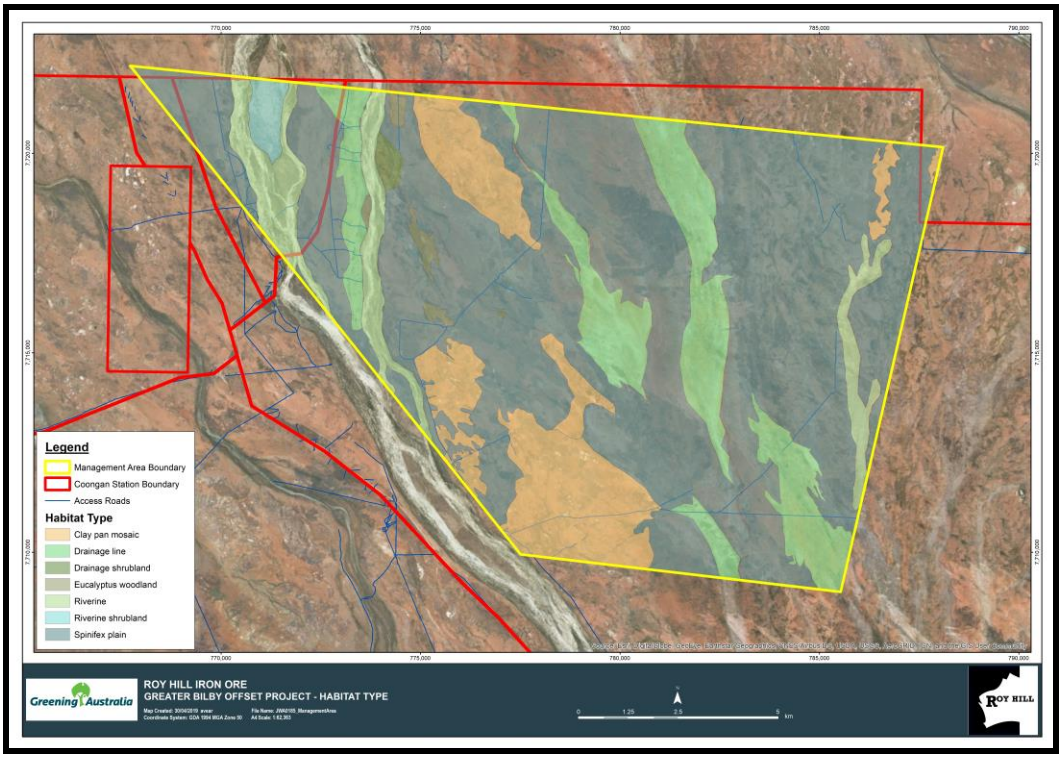

Figure 4: Vegetation types in the LMA.

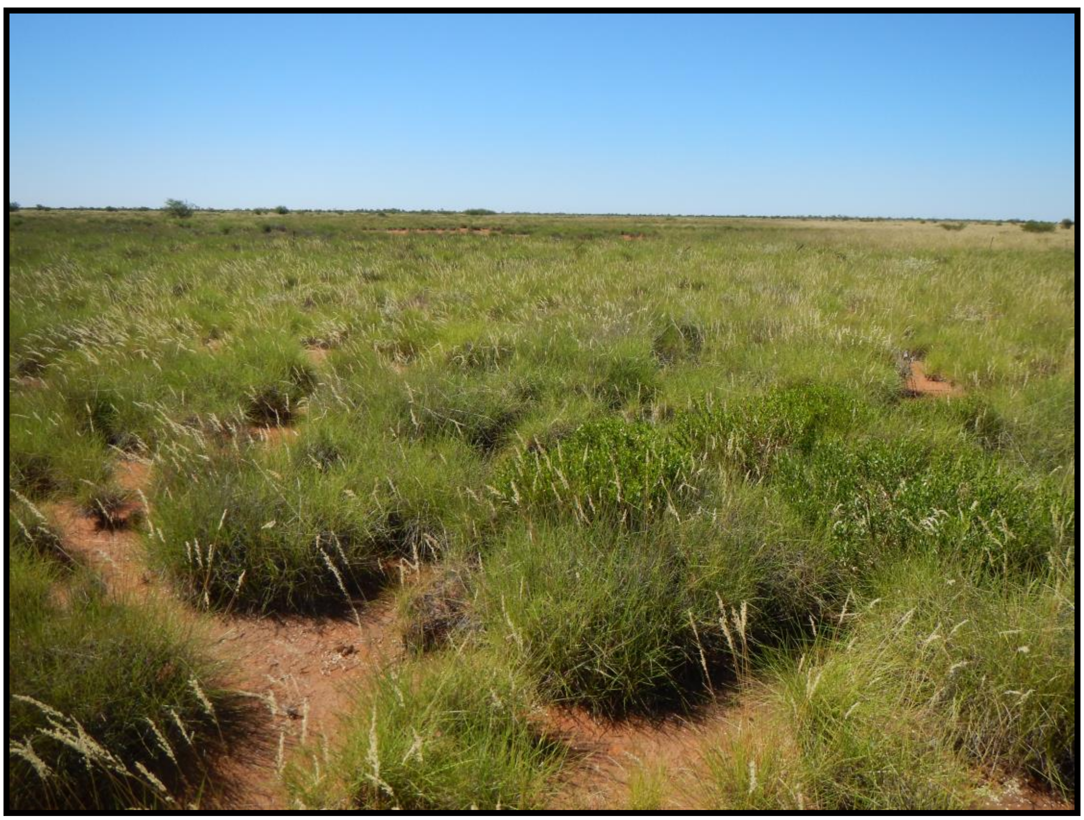

Plate 2: Spinifex plains form the dominant fuel type in the LMA.

The perennial spinifex plant is able to survive under conditions of extreme moisture stress. When under moisture stress, spinifex gradually shuts down photosynthesis and growth, withdraws chlorophyll from its leaves, maintains cell structure and integrity (i.e. does not wilt) through a complex and poorly understood physiological pathway and 'suspends' metabolism. Under severe water stress, the plant is straw-coloured, and has the 'cured' appearance of an annual grass. The moisture content of 'living' parts of the plant (root, stem and leaf) can fall as low as 12% and plants can remain partly desiccated for at least 2 years, beyond which they will eventually die. During prolonged dry spells, some plants will actually shed foliage to conserve water, giving clumps a sparsely foliaged appearance.

Following sufficient rainfall (>6-10 mm), within a short time, the plant imbibes soil moisture, mobilises chlorophyll and commences metabolism - photosynthesis and growth - including production of new foliage, flowering and stolon growth. When the soil is wet, the foliage is very green with the moisture content of live components reaching 70-80% and the moisture content of the whole plant profile, including live and dead components, reaching 40-45%.

After regeneration, usually from seed following fire and rain (some species will resprout), the spinifex plant develops through a variety of structural or architectural forms, starting as a small dome-shaped clump, and with age, taking on a 'donut' or crescent-shaped structure as stolons grow more-or-less radially, and older plant parts towards the centre of the plant die. Dead spinifex (grey-black colour) can persist behind the 'active growing front' of the plant for several years. Not only does the structure of the plant change with age, but so does the proportion of dead material in the hummock, therefore its flammability. Dead spinifex makes a significant contribution to the plant's fuel properties mainly because it is very responsive to changes in RH and to rainfall events. Dead fuel can remain very dry (<6%) for long periods on account of the low relative humidity normally experienced in arid and semi-arid environments.

The spinifex plants form a dominant, simplex, discontinuous fuel layer with flammable elements separated by bare ground patches of varying dimensions. Once the cover of spinifex exceeds about 30% and its biomass (fuel load) exceeds about 3-4 t/ha, it has the potential to sustain fire spread. Because of its patchiness, mature spinifex fuels have at least two fire spread thresholds - the first is fuel moisture content – when wet and fully 'green' fire spread will be difficult to sustain. However, the main threshold (for mature fuels) is wind speed. The wind speed threshold varies according to spinifex cover and moisture content, but is usually in the vicinity of 7-10 km hr^{-1} measured 1.5-2 m above ground. Because it is patchy and has several spread thresholds, spinifex is often referred to as a 'go-no go' fuel. Guides to predicting spinifex spread are provided by Burrows *et al*. (2014) and there is an example at Appendix 3. Fire in spinifex is capable of very high rates of spread - in excess of 15 km/h under conditions of heavy, dry fuel and hot, strong wind.

Buffel grass forms the other dominant fuel type in the LMA and dense meadows can form on some soil types following good rainfall. On curing, and in the absence of grazing, these meadows become highly flammable, capable of sustaining regular, high intensity, high speed fires. Normally, the minimum fire return interval for spinifex meadows in this region is 6-7 years (depending on rainfall) but buffel grass has the potential to burn annually or biennially. This high fire frequency exceeds the fire adaptive traits of many native shrubs, small trees and perennial herbs, causing them to decline (Schlesinger *et al*. 2013).

Plate 3: Virtually pure buffel grass meadows on the River Land landsystem in the LMA.

2.3 Topography

In the project area, spinifex and buffel grass-dominated landsystems are characterised by flat sandy plains with varying proportions of clay and aggregate, so topography (slope) plays a minor role in fire behaviour. The wide sandy river beds can stop the spread of fire perhaps except under the most severe fire danger conditions when embers could be blown across rivers (and other fuel breaks).

2.4 Fire history

The recent fire histories for Coongan and the LMA are shown in Figures 5 and 6. From Figure 7, it can be seen that the current fuel age class distribution is similar to the theoretical 'ideal' distribution (a negative exponential, or reverse 'J' distribution), especially for the greater area of the Coongan lease. The theoretical age class distribution represents how the landscape most likely looked under 'natural' conditions of lightning and traditional Aboriginal burning, and in the absence of suppression action. This applies to the fuel age class distribution metric only and not burn patch size – this is discussed later. The current, near ideal fuel age class distributions shown below are a good starting point for fire management. Such distributions are the most fire-stable scenario, meaning that it is not possible for a single *large* bushfire to burnt out all or most of the landscape – it is buffered from the 'mega-bushfire cycle' because of the distribution of low fuel ages in the landscape.

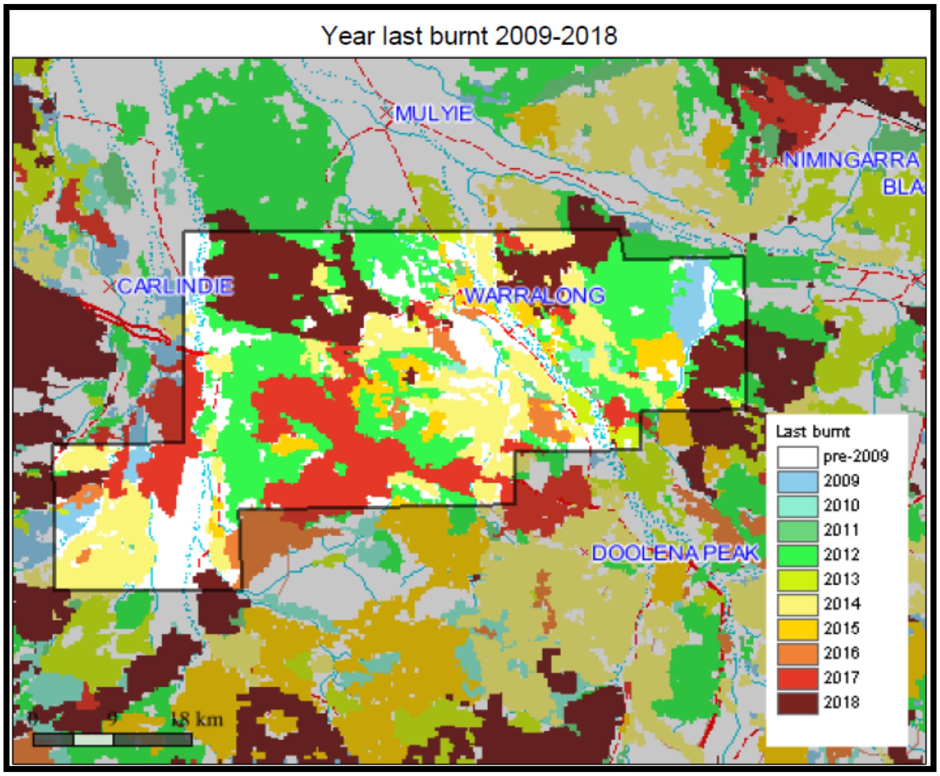

Figure 5: Recent (2009-2018) fire history for Coongan and surrounds. (Source: NAFI).

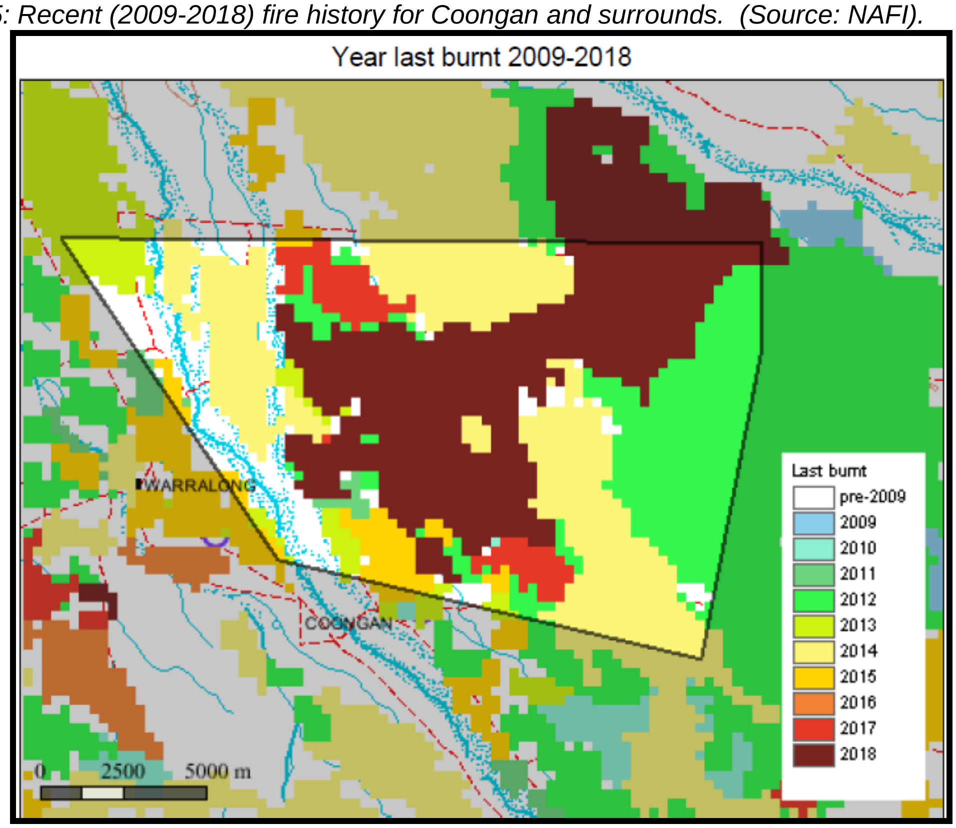

Figure 6: Recent (2009-2018) fire history for the LMA and surrounds. (Source: NAFI).

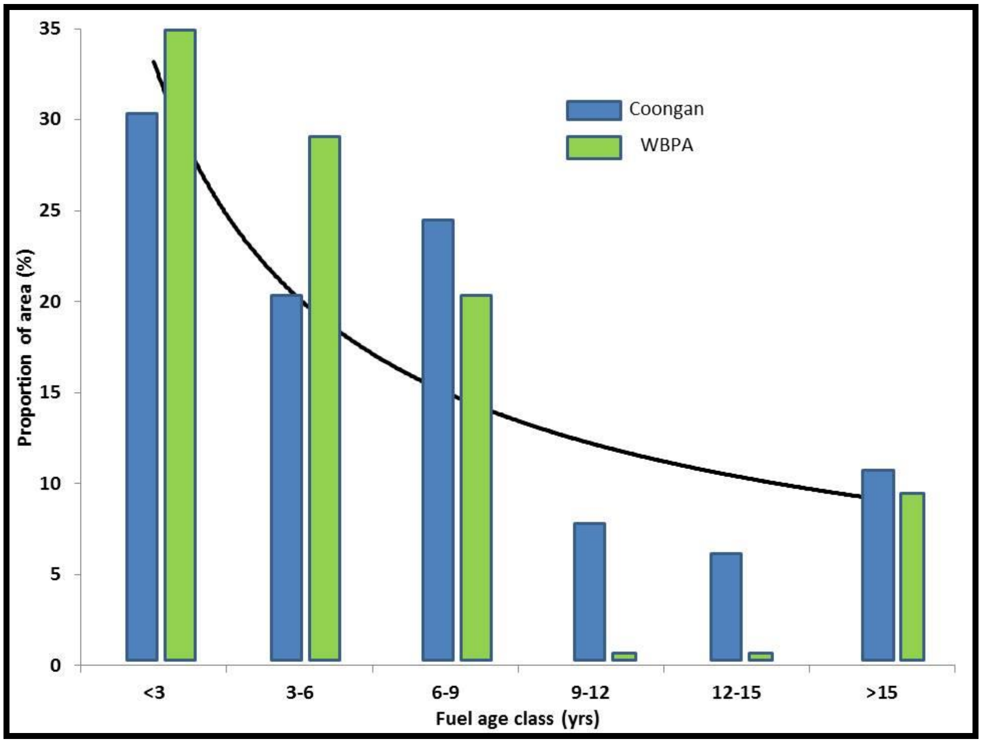

Figure 7: Actual and theoretical ideal (curved line) fuel age class distributions for Coongan and the LMA (2000-2018).

2.5 Fire ecology & fire regimes

Scientific knowledge of the ways in which spinifex ecosystems and species respond to fire is incomplete. Consistent with an adaptive management approach, this plan draws on best available science, indigenous knowledge, and experience to provide best possible fire management outcomes aligned with the objectives of the Offset Project and of the Coongan leaseholder. Rather than attempting to review and summarise all of the scientific literature on fire ecology in spinifex ecosystems (see Saxon 1984; Allan and Southgate 2002), available scientific knowledge, together with some knowledge of traditional Aboriginal burning practices, has been summarised into a set of principles to guide fire management. These are at Appendix 2.

In arid and semi-arid ecosystems there are key feed-back loops involving fire, vegetation, biome productivity and rainfall (Figure 8). Antecedent rainfall drives vegetation growth, which results in increased fuel levels and increased potential for large and intense fires (Griffin and Friedel 1984; Allan and Southgate 2002). Generally, periods of above average rainfall are followed by extensive fires due to the build-up of flammable fuel. Primarily through its influence on vegetation, rainfall also determines the quality of habitat available for animals, including cover, food and water resources, and nesting / breeding sites. The structural and biomass (fuel) dynamics of spinifex fuels in this subregion have not been studied, but in other lower rainfall bioregions, on average, spinifex fuel re-accumulates at ~0.6 t/ha/annum for ~18 years before stabilising at around 11-12 t/ha. This equates to ~400 mm of accumulated rain being needed to produce 1 t/ha of fuel. Because of the higher rainfall, rate of fuel accumulation is likely to be higher in this subregion. The bushfire cycle following periods of above average rainfall can be buffered, or interrupted by good fire management.

Season of the fire and post-fire rainfall will influence the composition, structure, biomass and speed of recovery of the vegetation (habitat) and its associated fauna. For example, Griffin and Friedel (1984a;1984b) working near Alice Springs found that winter fires favoured forbes and caused less physical damage to woody shrubs and trees than summer fires, which favoured grasses and stimulated better regeneration of some woody species.

Plate 4: A herbfield following recent fire (2018) and rain in a spinifex grassland on Coongan.

Unlike sclerophyllous vegetation that dominates much of southern Australia, spinifex-dominated ecosystems tend to follow a *pseudo-classical* succession post-fire. In the early post-fire period, annual and biennial herbs and soft grasses often dominate cover and biomass, with spinifex and woody shrubs present as either very small seedlings or as re-sprouts (Plate 4). With time, and depending on rainfall, the herbfield gives way to spinifex and a scattering of woody trees and shrubs, with spinifex eventually dominating the ground cover. The rate at which these ecosystems develop following fire is largely dependent on rainfall, which is variable from year-to-year. This makes predicting post-fire response and fuel accumulation imprecise and indicative only (see Burrows *et al*. 2008).

At various stages of post-fire development (seral states), the floristic composition and structure of the vegetation provides different habitat opportunities for a variety of animals. Data gathered either retrospectively or longitudinally for a variety of terrestrial fauna (vertebrates and invertebrates) show a consistent pattern – that there is no specific or optimal seral state, or time after fire, that suits *all* organisms (see Guiding Principles – Appendix 2). Some functional groups prefer the early seral states (recently burnt), others the later seral states (long unburnt) and some species occur in all seral states. This fundamental ecological principle of niche partitioning associated with diverse fire-induced habitats, coupled with fire stability, is the ecological basis for the fine scale mosaic or patch-burning strategy presented in this plan. This concept is summarised by Pianka (1996) writing about the richness of lizards in Australian deserts:

"*One of the most important factors contributing to this is fire, which generates a patchwork of habitats at different states of recover, each of which favours a different subset of lizard species. Habitat specialised species can go locally extinct within a given habitat patch (fire scar) but persist in the overall system by periodic reinvasions from adjacent or nearby patches of suitable habitat of a different age. Such spatial-temporal regional processes facilitate local diversity".*

Masters (1996) reported that a higher number of reptile species were trapped in mature spinifex and that fire mosaics maximise reptile diversity because of the preference by some species for earlier seral states. She also made the observation that recently burnt areas act as fire breaks and ensure that mature spinifex patches are always present. Langlands *et al.* (2012) studying the relationship between fire and spiders reported similar findings – that different spider assemblages preferred different post-fire states with about 50% of species restricted to a particular state. Similarly, Haydon *et al.* (2000) concluded that the patch-work of habitats at different stages of post-fire recovery (seral states) played a vital role in the conservation of biodiversity in desert landscapes. Smith and Morton (1990) studying scorpions in the Tanami Desert, found that one species (*Lychas alexanddrinus*) was caught most frequently 2-3 years after fire.

The relationship between patch-burning and small mammals is similar, but perhaps not as pronounced. Masters (1993) found that patch-burning spinifex grasslands to create a diversity of seral states maximised the species diversity of small mammals by ensuring that suitable successional states were always present. She concluded that this was particularly important for species that are restricted in their distribution such as mulgara (*Dasycercus cristicaudata)*. Letnic and Dickman (2005) working in the Simpson Desert found that while some species preferred long unburnt spinifex and others preferred regenerating spinifex, the greatest capture rates were made at sites that received most rainfall. Like Masters (1996), they concluded that recently burnt patches were an important part of the mosaic because they reduced the extent of bushfires. Partridge (2008) working in the Purnululu National Park concluded that small scale patchy spinifex fires were very important for *Pseudomys desertor* and *P. nanus*, which utilised long-unburnt patches for food and shelter.

Interactions between fire and predation by introduced predators can lead to dubious conclusions about habitat preference. For example, it was thought that mulgara were *only* found in long unburnt spinifex. However, monitoring at Lorna Glen (Matuwa) ex pastoral lease north east of Wiluna has shown that this species will inhabit recently burnt spinifex with low vegetation cover if introduced predators (feral cats, foxes, wild dogs) are reduced or eliminated, suggesting that the cover provided by longer unburnt spinifex is very important when predators are present.

2.6 Bilby and fire

Fundamentally, the bilby has a dependence on good fire management for food and cover. Southgate and Carthew (2006 and 2007) working in the Tanami Desert reported that seed from post-fire ephemeral plants such as *Yakirra australiensis* and other plants, are an important component of the diet of the bilby and that the season of fire, amount of rainfall post-fire and time since fire were most important in determining regeneration of *Yakirra*. Little Yakirra, or other food plants, was found in old, long unburnt spinifex. They also suggested that the best time to burn to encourage the successful regeneration and growth of important food/seed plants for bilbies was spring or early summer preceding the summer rains. The roots of some fire-promoted and relatively short-lived *Acacia* species host witchetty grubs ('lunki' – Martu), the larvae of a moth species, which are a food source for bilbies (N. Burrows personal observation).

There is little published information on the optimal fire regime for sustaining bilby populations (Pavey 2006; Cramer *et al*. 2018). Anecdotal evidence suggests that the combination of large hot bushfires and predation by introduced predators has caused the decline of bilby populations in the Pilbara and other arid and semi-arid regions of Australia. Bilbies are known to be able to co-exist with introduced predators such as feral cats and low levels of wild dogs when they have access to cover provided by dense spinifex. However, they are exposed to predation following large bushfires and at least two populations in the east Pilbara are known to have declined after being impacted by large bushfires (Martin Dziminski pers. comm.). Radio tracking of a bilby in the Gibson Desert Nature Reserve in the late 1980s revealed that the animal survived the passage of a large bushfire, but several days later was it was predated by a fox (Neil Burrows personal observation).

Based on available information, the most likely preferred habitat for bilbies in spinifex dominated landscapes is a mosaic of patches of recently burnt vegetation to provide food, and adjacent patches of relatively long unburnt vegetation to provide cover and shelter. Bilbies have been observed to move away from long unburnt spinifex, presumably because of lack of food resources (Martin Dziminski pers. comm.)

Plate 5: Introduced predators (cats, foxes and wild dogs) are a serious threat to native fauna.

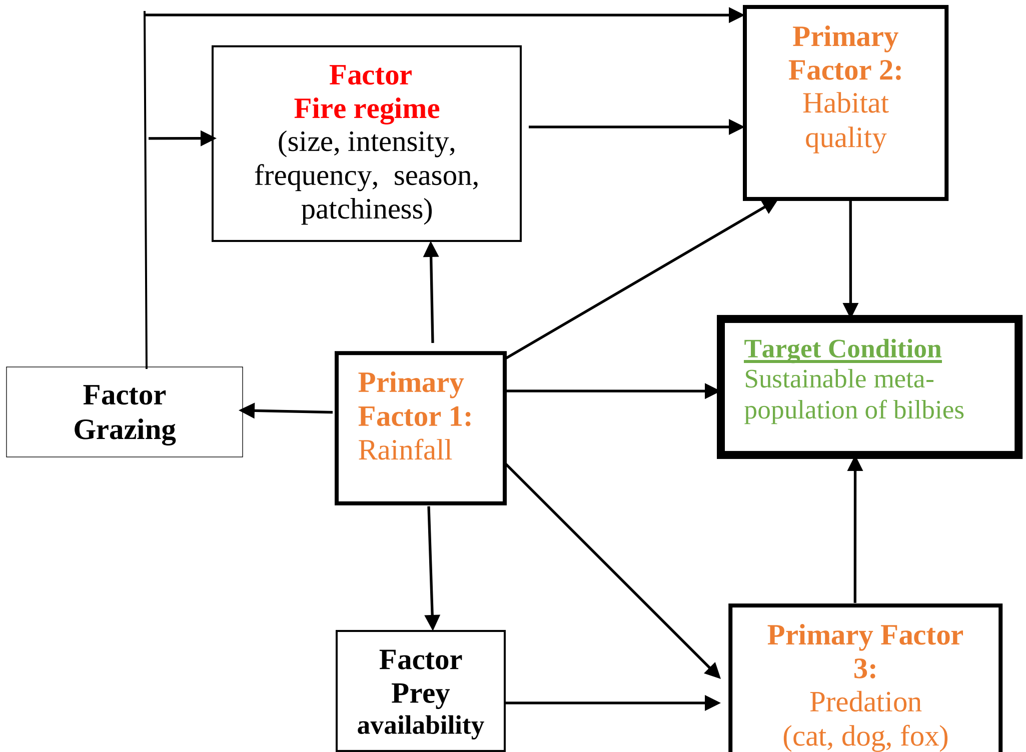

Figure 8: Simplified conceptual model of a management system showing interactions between the target condition (bilby population) and factors that influence the target condition, including fire regime and predation.

3. Fire management objectives

Conservation of the Coongan bilby meta-population is the primary focus of this project and of this fire management plan. While there has not been a comprehensive biological survey of the project area, there are other significant fauna and flora known to be extant in the Chichester subregion (see Kendrick and McKenzie 2001), some of which may occur in the project area and on Coongan lease. For example, there is evidence of mulgara on Coongan, including in the LMA. This fire management plan is also intended to be consistent with the management objectives for the Coongan pastoral lease.

This fire management plan is based on the hypothesis that:

i. A regime of large, hot bushfires is deleterious to bilbies (and to other wildlife and to pastoralism) (the term 'bushfire' is synonymous with 'unplanned fire' in this context).
ii. A fine-grain mosaic of different seral states (vegetation/fuel ages) is beneficial to bilbies (and to other wildlife and to pastoralism) because it promotes the regeneration of important food plants whilst retaining mature areas of sufficient high cover. It also buffers the bushfire cycle.

Therefore, the objectives of fire management are to:

i. Stop large, hot bushfires impacting the LMA and the Coongan pastoral lease.
ii. Maintain a fine-grain mosaic of vegetation at different seral stages (time since last fire) ranging from recently burnt to long unburnt.

To achieve these objectives, the plan has a two-pronged approach:
i. By ground burning, establish and maintain fuel reduced buffers around the LMA to stop the spread of bushfires and to assist with containing planned patch-burning (mosaic burning).
ii. Using a combination of aerial ignition and ground (hand) patch-burning (mosaic burning) to create and maintain a fine-grain mosaic of different seral stages (fuel ages) to provide habitat diversity and to fragment and restrict the run of bushfires. The composition of seral stages will aim to approximate the 'ideal' age distribution shown in Figure 7.

3.1 Co-benefits of good fire management

Inherent in the plan is the desire to build fire management capacity in the Warralong Community to enable sustainable, on-going fire management of the area by the community, which could include cultural burning and inter-generational transfer of knowledge. In addition to conservation, cultural and economic co-benefits, 'good' fire management will also result in a reduction in greenhouse gas emissions and an increase in carbon sequestration compared with an unmanaged fire regime (Burrows 2014). Once an approved methodology is developed, this could generate future economic benefit for landholders under the Federal Government's Emissions Reduction Fund.

The plan is designed to be consistent with fire management for nearby Yarrie Station (Legge *et al.* undated report) and to integrate with the aspirations of the Yarrie/Coongan lease holder.

Because of scientific uncertainty about fire behaviour and patchiness, and ecological responses in these ecosystems, the plan will be implemented in an adaptive management framework. The various assumptions and associated management activities will be monitored and evaluated, along with monitoring of the target species (bilby – reported elsewhere). Events such as floods and wildfire will be recorded as will local weather. Monitoring data will be continually evaluated, and if necessary, fire management will be adjusted in the light of new information.

4. Fire management strategies

Key performance Indicators (KPIs) are based on the fire management plan objectives defined above, and are described below. Fire KPI metrics are detailed in Section 5 below.

Fire KPIs:
- Extent of unplanned bushfire
- Burnt patch size
- Proportion of the landscape at various burnt patch sizes
- Proportion of seral states (fuel ages)
- Distribution of seral states

- Asset protection (fences, stock, etc.)

Capacity building and collaborations

- Engagement with Warralong Community
- Collaborations with leaseholders and fire and land managers

The following provides strategies to achieve objectives, and some metrics for the fire KPIs.

4.1 Buffer burning

A ~40 m deep fuel reduced buffer will be installed on the northern, eastern and southern boundaries of the project area (Figure 1) to stop bushfires entering the LMA and planned fires leaving the LMA. The actual location of the eastern and southern buffers is to be rationalised with the roading/track/fencing requirements of the Coongan lease holder but are nominally as shown in Figure 1. This will be achieved by:

i. Cleaning up the existing track on the northern boundary to create a 5 m wide mineral earth break. The boundary is ~19 km long (Plate 6). A new fence, including a wide easement, has been constructed along a significant distance of the northern boundary, so depending on vegetation growth over the next 12 months, this section may not need attention (Plate 7). To reduce the risk of erosion, track clean-up / construction will need to be done by skimming the vegetation off the track to minimise soil disturbance and the possible installation of whoa-boys (water bars) by an experienced grader operator.
ii. The proposed eastern and southern boundary tracks are over-grown and will require significant work to re-open them to 5 m. The eastern boundary is ~12 km and the southern boundary is ~8 km. The position of these boundaries may be adjusted and rationalised to fit with any plans the leaseholder has for fencing or opening up or constructing tracks to the east and south of the project area to access water points.
iii. The Coongan River and the wide main road west of the river provide an adequate fuel break on the western boundary.
iv. The above buffer burn preparation works need to be completed by June 2020.
v. When burn preparation is completed, buffer burning can commence at any suitable weather times over the period mid-June – early August. A burn permit will be required from local government and endorsed by the land holder, and a regular weather forecast (from Meteye online) will be required to properly safely plan and implement burning. A Kestrel® hand-held weather station can be used to measure and record weather variables during burning.
vi. Burning technique will involve a 5-6 person crew sourced from the Warralong Community– three people with drip torches (lighters), one or two on a truck (heavy duty appliance, 2500-3000 l of water) and one in a 4x4 light unit (400-500 l of water). Following a briefing, including a safety briefing, the buffer will be burnt by three lighters with drip torches working in staggered (echelon) formation upwind of the track, allowing the fire to burn with the wind back to the track. The first lighter will walk a few meters off the track on the upwind side, creating a strip of back fire upwind of the road. The second lighter will walk a safe distance behind the first lighter and about 20 m upwind, and the third lighter will walk behind the second lighter and some 40 m upwind (Figure 9). Depending on fuel and weather conditions, the fires may or may not run. If fires don't run, then 'cold' burning will need to be employed –i.e. burning individual hummocks to obtain a ~40 m buffer (< 25% cover of fuel).

Plate 6: A section of track on the northern boundary needing a clean-up before buffer burning.

Plate 7: Recently constructed easement and fence on the northern boundary of the project area.

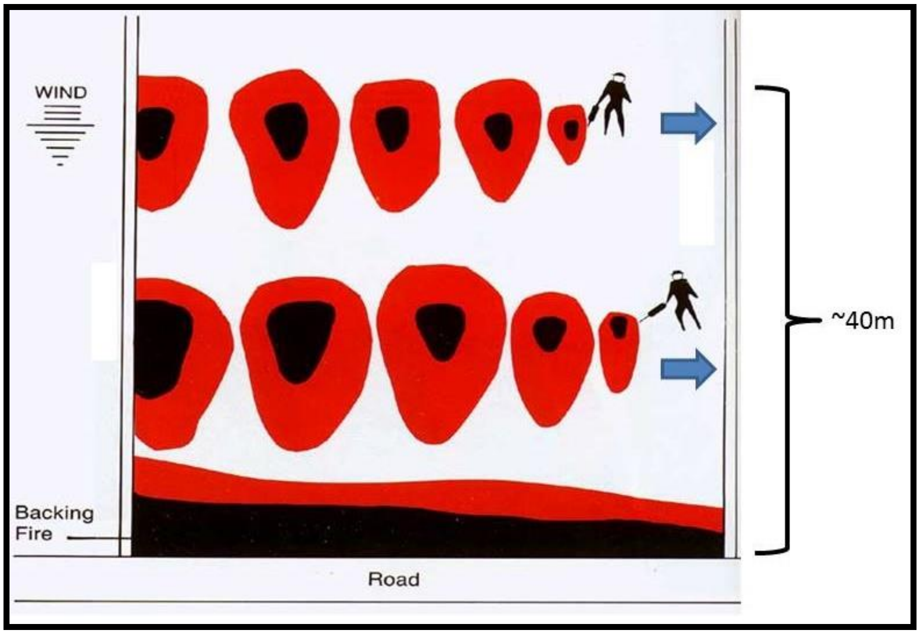

Figure 9: Illustration of echelon lighting technique showing lighters 2 and 3 – lighter 1 has lit the backing fire adjacent to and upwind of the road / firebreak.

vii. In most cases in spinifex, the back fire will self-extinguish. Where this doesn't occur due to high fuel cover, it will be extinguished using the light unit. The reason for this is in case of a wind change – a cool burning backfire can become a hot running head fire. The truck is on site to provide water for suppression and mop-up should it be needed.

viii. All going well, buffers should be able to be installed at a rate of about 1 – 1.5 km per hour.

ix. Resources needed:
   a. 5-6 people under supervision and with appropriate training and PPE. People will come from the Warralong Community;
   b. 1 heavy duty appliance (truck) – possibly sourced from DFES Marble Bar volunteer Emergency Services Unit (to be followed up), and 1 light appliance possibly sourced from DFES or Parks and Wildlife Service Karratha (to be followed up). (May be an issue getting plant across the river?).
   c. 4 drip torches plus fuel.

4.2 Developing ecological fire regimes

While the principles at Appendix 2 guide fire management, the development of specific, operational fire regimes for bilby conservation and biodiversity conservation generally in these landscapes, is challenging but necessary. The most critical elements of fire regime and mosaic metrics for spinifex-dominated ecosystems are;

- fire return intervals,
- fire size and patchiness,
- proportion (% area) of the landscape at various seral (post-fire) states and how these patches are distributed in the landscape, and,
- seasonal timing of fires in relation to events (rainfall) that drive plant and animal reproduction / productivity.

4.2.1 Fire return intervals

This regime element is important, primarily because it influences ecosystem resilience, or capacity of the vegetation to recover / regenerate following fire. Generally, the post-fire response of other species will be determined by the recovery pathway of the vegetation. Fundamentally, fire interval determines the size and viability of seed banks, fuel load/fuel hazard, structure, floristic composition and the energy reserves of storage tissue used by re-sprouters such as lignotubers, bulbs, corms and epicormic shoots. It also affects potential fire behaviour.

Plant vital attributes and life histories can be used to guide the range of appropriate fire intervals (Tolhurst 1999; Tolhurst 2000). This involves identifying the vital attributes of key 'fire response species', which could be fire sensitive (umbrella species), keystone species or threatened species. Key fire response species are those that are most sensitive to fire because they are most likely to be disadvantaged by excessively short or long fire intervals. Having identified the key species it is possible to determine the time interval between fires required to conserve species, i.e. the maximum and minimum intervals between *lethal* fires (Friend 1999; Tolhurst 1999; Burrows *et al*. 2008). Note – the distinction between lethal and non-lethal fires, so in addition to vital attributes, fire intensity and patchiness is important in determining 'fire sensitivity'.

Time to first flowering after fire (juvenile period) is an important vital attribute as it indicates maturation and seed production. Muller (2005) provides information on post-fire regeneration strategies and juvenile periods for a range of arid zone plants, based on observations of largely Pilbara flora provided by Stephen Van Leeuwen (DBCA). From this, it is clear that a) most species in these environments depend on seed for regeneration following fire, b) a number of tree-form (arborescent) acacias such as mulga, have juvenile periods >10 yrs, c) all other species have juvenile periods <10 yrs with most <5 yrs. There is at least one taxa for which information about juvenile period and longevity is important, namely spinifex – because it is a keystone species in these landscapes and is the dominant fuel (except where it has been displaced by buffel grass).

Based on studies from other arid regions, following average or better rainfall, precocious spinifex plants have been observed to flower within 2 years of fire. However, for the Chichester subregion, a more realistic time period for at least 50% of the population to reach maturity, and assuming average rainfall conditions over that period, is 3-4 years. Gill and Nichols (1989) provide a rule of thumb of allowing a minimum inter-fire period of at least twice the juvenile period for post-fire recovery of seedbanks. For spinifex ecosystems, a conservative minimum fire interval in this subregion, given conditions of average rainfall, is probably 6-8 years. While spinifex ecosystems could recover from an occasional shorter fire interval, 6-8 years is considered a safer interval under average rainfall conditions over the period. It is unlikely that fuel would be such that fires could be sustained in spinifex at an earlier age – the exception being after a sequence of above average wet seasons and proliferation of herbs and soft grasses. There have been observations in desert biomes where fires have occurred two years apart following good seasons, transforming spinifex dominated communities to simplified soft grass (*Eragrostsis* sp.) and herb communities (N. Burrows pers. obs.).

There are few biological indicators of the maximum interval between fires in the spinifex dominated landsystems. One of these is the biomass, structure and vitality of spinifex plants. Clearly, it is desirable for a fire to occur before ageing spinifex plants (and other species) loose their vitality, seed production potential and their seed banks. The vigour of spinifex begins to decline from the time the plant centres die (Griffin 1984). While spinifex will recruit between fires, the combination of fire and rain provides conditions for a mass recruitment event, which is why many spinifex communities appear even-aged – although it is not uncommon for late seral state populations to be multi-aged suggesting several inter-fire recruitment events – possibly stimulated by exceptional rainfall. From field observations, spinifex biomass declines and plants appear to break down and senesce around 30-40 years after fire. Not only does this reflect a reduction in productivity and possible decline of seed banks, but the fuel can reduce to a point where fire spread cannot be sustained except under the most severe fire weather conditions. As fire and its associated by-products (heat, smoke, ash) are vital to cueing seedling germination of many species, including spinifex, this is undesirable.

As a rule of thumb based on biomass accumulation, height and cover of spinifex, the maximum interval between fires should not exceed 25-30 years - until there is better information, or an identified need to alter this period such as retaining a very long unburnt fire reference area for scientific purposes. This figure is consistent with Griffin (1984) who suggests that optimum maturity is reached after 8,000 -10,000 mm of (accumulative) rainfall. Assuming an annual average rainfall of 300-350 mm, this equates to about 25-30 years.

4.2.2 Fire size and patchiness

Fire size and patchiness is a factor that is more relevant to animals than plants, although it may be applicable to seed dispersal of some species such as wind-borne grass seeds or propagules relying on animals for dispersal. When large areas of a landscape are subjected to a single, homogenous disturbance such as a large, intense fire, then this will diminish habitat diversity and threaten fauna that depend on a variety of habitats, or seral states (Miller 1982, Saxon 1984). Fire size determines the patch size of the various fire-induced habitat types (seral states), therefore the juxta-position of various habitats in the landscape. For fauna that have specific habitat requirements with respect to seral state, they are more likely to find suitable habitats and refugia in a landscape where patch sizes are 'small' rather than 'large'. Such a landscape facilitates recolonisation and the functioning of meta-populations – i.e. migration and the functioning of sources and sinks. The assumption is that smaller patches make the landscape more 'permeable' to fauna.

There are no sound biological indicators or evidence of the optimum scale of fires in spinifex ecosystems. From first principles (see Appendix 2), small fires / patches make better ecological sense than large fires for the reasons given above. While there is inherent patchiness in large and intense bushfires, unburnt patches within hot bushfires, as important as they are, are usually small and scattered compared with the size of burnt patches.

Table 2 summarises burnt patch metrics for remote Western Desert landscapes studied by Burrows and Christensen (1990), Burrows *et al*. (2006) and Bliege-Bird *et al*. (2012). The table includes a summary of burnt patches mapped from 1953 aerial photography in a remote desert location that was under a regime of traditional Aboriginal (Pintupi and Martu) burning at the time of the photography, providing a rare insight into the fire landscape. Gill (2000) cautions that large tracts of central Australia may have been unoccupied by Aboriginal people, so subjected to lightning ignitions only.

Table 2: Recently burnt patch statistics for Western Desert landscapes under traditional Aboriginal burning.

Source	Area sampled (ha)	No. of recently burnt patches	Mean patch size (ha)	Median patch size (ha)	Range (ha)
Burrows & Christensen (1990) 1953 aerial photography	53,483	372	34	5	0.5 -1,744
Burrows *et al.* (2006) 1953 aerial photography	241,219	846	64	6	0.5 – 6,005
Bliege Bird *et al*. (2012) contemporary satellite imagery of Martu hunting fires		3856	217	4	

While these statistics are interesting and provide some information about patch size under traditional Aboriginal burning, they do not reveal the full picture – the proportion of the landscape affected by various fire size classes. That is, while small patches were most numerous, the larger patches, although fewer, made up most of the burnt landscape. While the means and maxima varied between the three studies in Table 1, the median patch size was about the same (4-6 ha). The authors concluded that such small patch sizes were achieved by purposeful and frequent introduction of fire into the landscape. However, within several decades of the cessation of Aboriginal burning, the mean, median and maximum patch sizes had increased to 4,970 ha, 390 ha and 71,346 ha respectively. These studies were done beyond the pastoral 'belt' – so this dramatic change in fire regime may have been modified to some extent on pastoral lands as a result of grazing and burning.

Griffin and Allen (1984) recommend some eleven different patch sizes for a variety of land units in the Uluru National Park, ranging from 1-5 ha patches within mulga groves, to 400-500 ha patches within sandplains. Burrows and Butler (2014) recommended keeping the mean burnt patch size < 100 ha with the median patch size <10 ha, accepting that larger fires will inadvertently occur and that under traditional Aboriginal burning in the Gibson Desert, some 70% of the landscape was burnt by patches >100 ha but <6,000 ha.

These statistics refer to large scale landscapes of the Western Desert beyond the pastoral zone so are a guide only for landscapes of the Chichester subregion. With respect to fire, the Warralong Bilby Project area should be managed as part of a larger landscape, at least as part of the Coongan pastoral lease, the boundaries of which define individual fire management responsibilities. With this in mind, see the patch-size recommendations in Section 7 (below).

4.2.3 Proportion and distribution of seral states

In flammable ecosystems such as hummock grasslands, and in the absence of suppression activity, the form of the relationship of the proportion of the landscape at various seral state / fuel age classes will approximate a negative exponential (Tolhurst 1999; Tolhurst 2000; Wouters *et al.* 2000). That is, a greater proportion of the landscape will comprise early and intermediate seral states, or younger fuel ages. The reverse of this, i.e., the majority of the landscape being of late or very late seral state, or old fuels, is unstable and impossible to maintain in the longer term in the absence of a supreme suppression effort. That is, a 'bushfire cycle' of regular, large hot fires will be established without regular proactive prescribed burning. The shape of the negative exponential will depend on several factors, including fire frequency, or the number of ignitions in the landscape, and the assumption that all parts of the landscape have the same probability of ignition. The shape of the negative exponential for particular vegetation types can be theoretically / mathematically derived by various plant life history attributes such as juvenile period and longevity of key fire response species, and this shape used as a basis for determining the *theoretically* ideal proportion of the landscape at various seral states / fuel ages (see Tolhurst 2000; Tolhurst and Friend 2001).

Using this methodology, it is appropriate to use a single idealised fire age class distribution for the spinifex-dominated landsystems based on the vital attributes and fire cycle of spinifex, the keystone species in these systems. An example of this, taken from Burrows and Butler (2013) and adjusted slightly for the higher rainfall environment of the current project areas, is shown in Figure 7 above.

Annual mosaic burning programs can be planned by comparing the actual seral state / fuel age distribution to the theoretical idealised age distribution to identify age classes that are over or under represented in the landscape. These can then be targeted for burning if over represented, or exclusion from burning if under represented.

Another related approach, one that is more biologically meaningful in ecosystems of annual rainfall variability, and simpler and more practical to implement, is to determine the desired proportion of the landsystem at various seral states, or functional habitats, where a functional habitat is a combination of fuel age classes and reflects the state of the vegetation as habitat (structure, cover, biomass, etc.) rather than its specific age/time since fire – see below. This also helps to 'even out' year-to-year variability in rainfall and consequent biomass productivity.

- Early seral state: fuel age <7 yrs or <1800 mm accumulated rain since fire
- Intermediate seral state: 7-15 yrs or 1800-4500 mm accumulated rain since fire
- Late seral state: >15 yrs or > 4500 mm of accumulated rain since last fire

The above classes are loosely based on the developmental stages of spinifex (cover, structure, biomass), although the actual class boundaries are somewhat arbitrary. The accumulated rainfall figures are a reminder that post-fire development is dependent on rainfall rather than time since fire *per se*, so the times may alter depending on rainfall. Using these seral state classifications and the proportions (%) shown in Figure 7, the theoretical ideal distribution of seral states / functional habitats in spinifex-dominated landsystems is as summarised in Table 3 below. Due to the constraints of prescribed burning and unknowns such as bushfires, it will be difficult, if not impossible to precisely meet the theoretically ideal seral state distribution, but it provides guidance and a target for fire management.

Table 3: Simplified theoretical idealised proportion of functional habitats (seral states) for spinifex plains based on vital attributes of keystone species (Triodia spp.) and adapted from Burrows and Butler (2013).

Seral state	**Early (<6 yrs)**	**Intermediate (6-12 yrs)**	**Late (>12 yrs)**
% of Landscape	50%	40%	10%

Seral states should be a dispersed (rather than clumped) in the landscape to maximise habitat boundary, edge effect and the total distance of boundaries between different seral states, and to break up the run of bushfires.

4.2.4 Season of burning

There are several factors that influence when to burn. Probably the most ecologically significant of these is the timing of fire in relation to rainfall, which will strongly influence the early post-fire recovery rate and regeneration success. Because rainfall is unreliable and difficult to predict, the timing of burning can only be planned around those times of the year when statistically, burning is most likely to be followed by rainfall within several months. From Figure 2 above, burning during the period September to December increases the likelihood of follow-up rainfall within several months to stimulate regeneration. Southgate and Carthew (2007) also recommended burning in late spring – early summer to optimise the chances of *Yakirra* regeneration, and other ephemeral post-fire herbs that are an important food resource for the bilby.

However, this time of year is usually too ‘hot’ and fuels too dry for safely implementing cool, small, patchy burns. Therefore, a safer time is over the winter months of June, July and into mid-August at least until the fuels are ‘broken up’ by cool patch-burning so that large bushfires can’t develop. Once this is achieved, and buffers are in place, burning later in the dry season can be contemplated. In my experience, pastoralists will often burn during or soon after mustering, or after rain, which may also be an option once risks of escape or large fire development have been assessed. Tying or running burns into previous recent burns (burn stacking) is a relatively safe way to proceed.

The other important factor determining ‘when to burn’ is the fire danger rating, or the ease of controlling or managing fire spread and fire size, which, in spinifex fuels, is primarily a function of wind speed, fuel cover and fuel moisture content. The combination of warm dry weather and relatively high wind speeds over the spring – early summer period (September to December) increases the fire danger rating and the potential for fast-spreading, large fires, compared to autumn – winter when the fire danger rating is generally lower.

For burn security and during the early stages of re-establishing a fine scale patch-burn mosaic, it will be prudent to establish the low fuel buffers along roads and tracks that form the perimeter of the LMA, as described above. Once buffers are in place, mosaic patch-burning could be carried out within these buffers later in the dry season (late spring, early summer). Burning conditions (weather) can be quite severe over the late spring and summer months with the potential for very fast spreading fires, so necessary precautions will need to be taken (see below). With the summer rainfall bias, there will likely be opportunities for burning after good rainfall events in summer.

In addition to providing a level of burn security and fire size containment, buffer and strip burning under marginal burning conditions will also add to the fire diversity of the mosaic.

5. Patch-burn targets

5.1 Patch- burning for bilby habitat (and other values)

While bilby conservation is the key management objective for this project, management actions to protect and conserve the bilby will likely benefit other conservation, economic (pastoral) and cultural values – that is, managing for the bilby will have co-benefits. Ecologically-based fire management is essential to achieving this objective.

Proactive fire management (prescribed burning) is necessary to create and maintain suitable habitat and to mitigate the adverse impacts of bushfires. The optimal range of burnt patch sizes in these landscapes is unknown, but the targets below are based on 'expert opinion' stemming from knowledge of traditional Aboriginal burning practices and a sense for bilby habitat requirements. Because of the variability of weather, burning conditions, unplanned fires etc. it will be difficult to precisely meet the following targets, but they provide a guide and something to aim for and to test in an adaptive management framework.

Patch-burning can be carried out by on-ground hand burning and by using aircraft, if this asset is available. The specific, quantifiable fire management targets to support bilby conservation on Coongan spinifex grasslands including the LMA are:

- To create and maintain a fine scale mosaic of diverse seral states and functional habitats with the following characteristics and metrics:
    - Fire return intervals: Min 6 yrs, max 25 yrs
    - Burnt patch size:
        - Mean ~200 ha
        - Median ~20 ha
        - Maximum ~ 1,000 ha
    - Acceptable limits:
        - 35% of landscape: patches < 350 ha;
        - 35% of landscape: patches 350 ha -800 ha
        - 30% of landscape: patches 700-1,000 ha
    - Contain bushfires to <1,000 ha.
    - Proportion of seral states (from Table 3 above):
        - Early ~ 50%;
        - Intermediate ~ 40%;
        - Late ~ 10%;
    - Scattered distribution of seral states to optimise habitat boundary.
    - Season of fires:

- Fuel management (buffer / edge / strip) burns: Winter or when weather conditions are suitable, such as after significant rainfall when fuel moisture content has increased. The tactic is to burn under marginal burning conditions such that head fires will just spread. The actual weather conditions to achieve this will vary according to fuel cover and dryness.
- Ecological (patch) burns: Winter-spring, or after significant rainfall when fuel moisture content has increased.

5.2 Patch-burn prescription

The current fuel age distribution (Figure 7) can be used as a guide to determine which areas should be patch-burnt during the life of this plan. The strategy is to target those areas with fuel ages in excess of the 'theoretically ideal' proportions. Figure 7 shows that the 6-9 year old fuel age class is over-represented, so should be targeted for patch-burning, with the aim of burning about 20% of this age class in 2021.

Managing the size of burnt patches relies on the fires going out before they get too large. This can be done by selecting the right fuel and weather conditions, especially wind seed, under which to carry out burning, by manipulating the lighting pattern (the location of ignition points) and / or by using existing recently burnt patches to manipulate fire size – i.e., by running fires into recently burnt patches.

In any event, burning should only be undertaken when conditions are mild – that is, the weather conditions, including temperature and especially wind speed are mild and fuel moisture content is relatively high. Experienced spinifex burners will intuitively know and understand the best conditions of fuel and weather for safe controlled burning. To assist with decision-making and for those with less experience, a science-based spinifex fire behaviour guide is at Appendix 3. Table 4 below contains a guide to conditions for low intensity patch-burning. Although these models are based on the results of some 200 experimental fires, they are guides only with a reliability of about 75%.

Depending on the extent to which it has been 'eaten out', and its degree of curing, fire in buffel grass will behave differently to spinifex. The CSIRO Grassland Fire Behaviour model provides guidance to fire behaviour in buffel grass.

Table 4: The likelihood of fire spreading in a 8-9 year old spinifex meadow with 40-45% cover and various degrees of curing (colour of the clumps – moisture content) and wind speed; Assumes no recent rain and air temperature 25-35^{o}C . Y= spread likely; N=spread unlikely. Green = preferred patch-burn conditions. Red = fire likely to be very active.

Spinifex colour (curing)	Wind speed (km/h)			
	<5	5-10	11-15	16-20
Green	N	N	N	Y
Green-yellow	N	N	Y	Y
Yellow-green	N	Y	Y	Y
Yellow	N	Y	Y	Y

6. Capacity building, Warralong Community

The expectation is that the on-ground, hand burning of the WBPA will be undertaken by the Warralong Community. This will require training and co-ordination of community members. It is beyond the scope of this plan to prescribed how the community will be engaged and coordinated for training and fire management, but the actual fire training component is within scope.

6.1 Basic fire training

DFES will be approached to provide on-site pre-season mandatory and Level 1 Fire training to appropriate participants from the Warralong community. This to include operation of the heavy duty and light duty firefighting appliances (probably ex Marble Bar). It may also be necessary for some community members to hold a truck licence to drive the heavy duty appliance. (Note – formal discussions are yet to be had with DFES, the Marble Bar Volunteer Emergency Services Unit and the Shire of East Pilbara about this project and about the involvement of these organisations).

Hands-on (in the field) training will be provided by Neil Burrows during the implementation of the strategies described above (buffer burning and patch-burning).

7. Preliminary works schedule

Table 5 below lists tasks and timelines for the implementation of this four year fire management plan (2019-2022). During this period, buffer burning and patch-burning of WABP will only need to be done once. It would also be advantageous to the project if some aerial patch-burning could be undertaken on Coongan surrounding the WABP area and during the planning period, but this will be at the discretion of the lease holder.

Implicit in this schedule is the requirement to update the fire history maps and associated metrics annually and at the end of each fire season based on NAFI - MODIS derived imagery. Because of uncertainties about fire patterns resulting from prescribed patch-burning and wildfires, this up-dated information is essential for planning and implementing the next stage of burning activities. That is, specific detail about planned burning cannot be pre-empted beyond the next fire season.

In addition to training, there will be a requirement to provide PPE for the Warralong fire crews, as well as drip torches. It is anticipated that firefighting appliances (1 heavy duty truck, 1 light duty fast attack) will come from the Marble Bar DFES Emergency Services Unit – this to be discussed with DFES and the Shire of East Pilbara as part of the stakeholder consultation.

Table 5: Proposed works program 2019-2022.

Task	By whom	By when
Stakeholder consultation re fire management plan: • Nomads Foundation • Outback Beef (Annabelle Coppin) • Warralong Community • Adjoining land holders • Shire of East Pilbara • Marble Bar Emergency Services Unit • DFES • DBCA Pilbara Region • Other?	Greening Australia with support from Harriet Davie (Roy Hill Iron Ore) and Neil Burrows if needed.	November 2019
LMA track perimeter clean-up and buffer burn preparation	Greening Australia to co-ordinate. In consultation with Annabelle Coppin.	Before June 2020
Level 1 Basic Firefighter training – Warralong Community	Greening Australia and Neil Burrows to liaise with DFES for on-site-training.	Before June 2020
'Hands on' fire training Warralong	Neil Burrows	June-July 2020 as part of on-ground buffer burning and patch-burning operations
Burn permits ex Shire of East Pilbara	Neil Burrows to arrange with Annabelle Coppin (permit requires landholder endorsement)	June 2020
WBPA perimeter buffer burning	Greening Australia to coordinate, Neil Burrows to supervise on-grand	Burning to be done June-July 2020
On-ground targeted patch-burning of the WBPA area	Greening Australia to coordinate, Neil Burrows to supervise on-ground	Burning to be done July-August 2021
Aerial patch-burning Coongan lease	At the discretion of the leaseholder	At the discretion of the leaseholder

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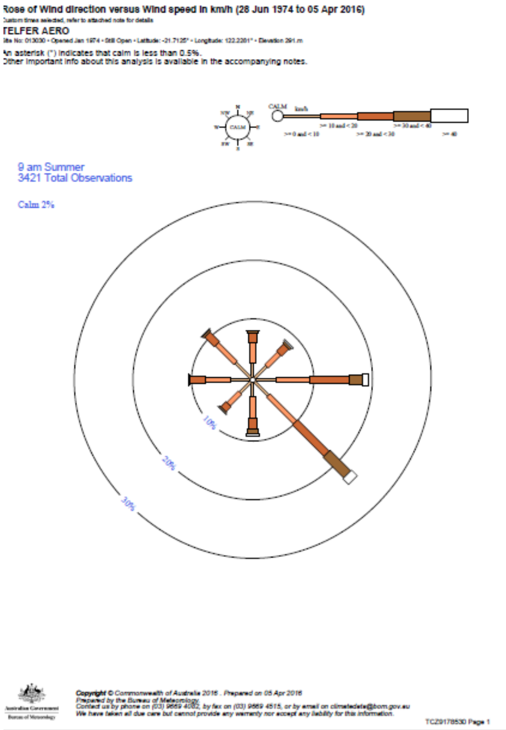
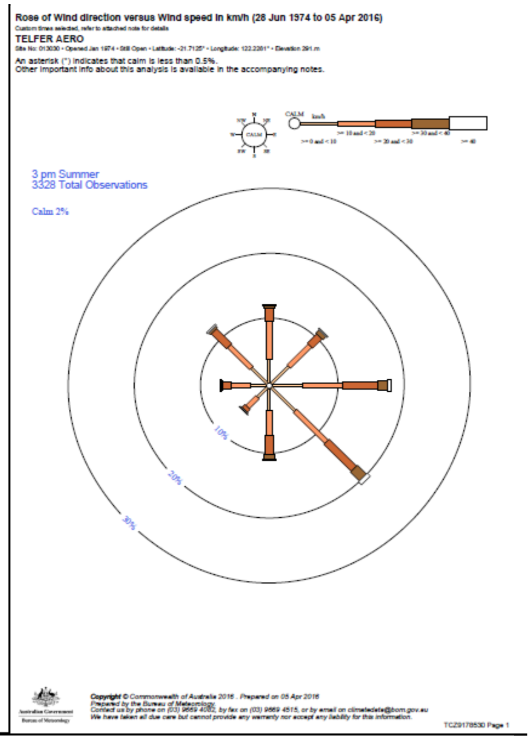
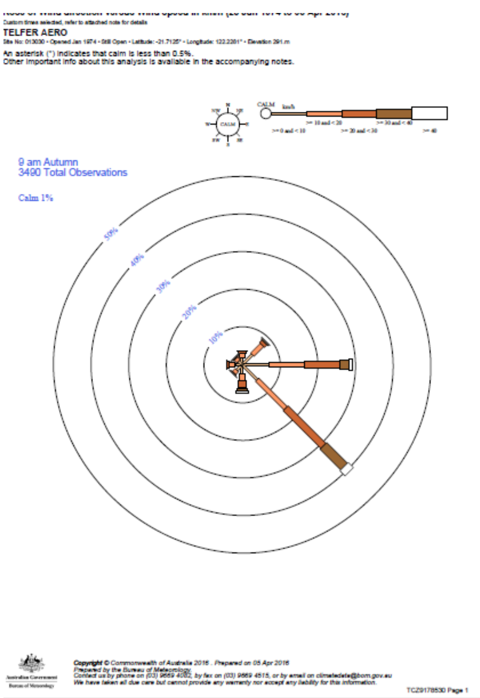
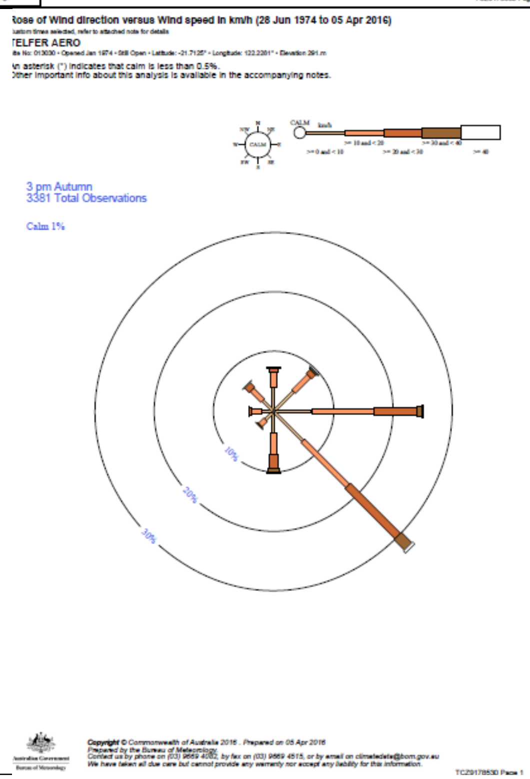
Appendix 1

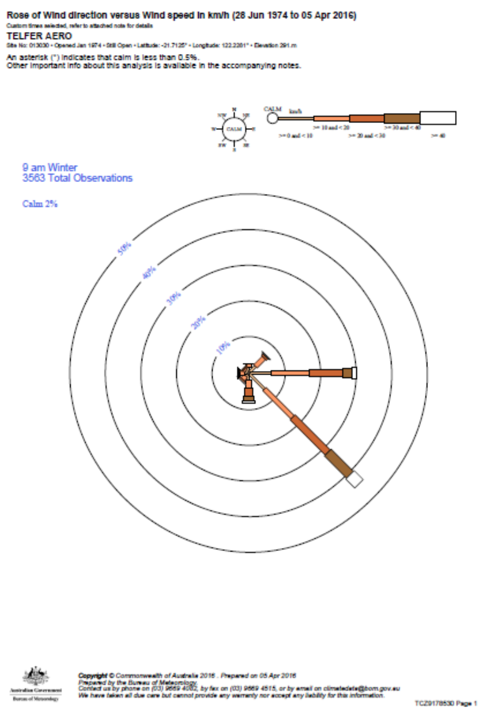
Mean monthly 0900 hrs and 1500 hrs wind speeds and direction for Telfer (source: BoM).










Rose of Wind direction versus Wind speed in km/h (28 Jun 1974 to 05 Apr 2016)
Custom times selected, refer to attached note for details
TELFER AERO
Site No: 013030 • Opened Jan 1974 • Still Open • Latitude: -21.7125° • Longitude: 122.2281° • Elevation 291.m
An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.
CALM
km/h
>= 0 and < 10
>= 10 and < 20
>= 20 and < 30
>= 30 and < 40
>= 40
9 am Winter
3563 Total Observations
Calm 2%
50%
40%
30%
20%
10%
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Prepared by the Bureau of Meteorology.
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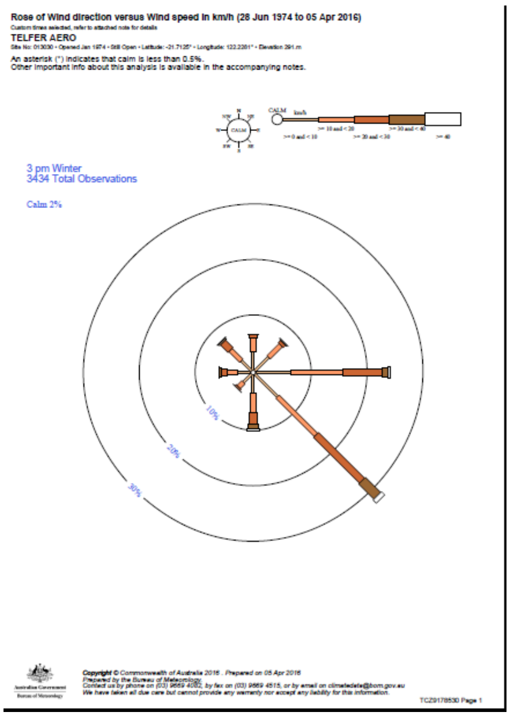
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An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.
CALM
km/h
>= 0 and < 10
>= 10 and < 20
>= 20 and < 30
>= 30 and < 40
>= 40
3 pm Winter
3434 Total Observations
Calm 2%
10%
20%
30%
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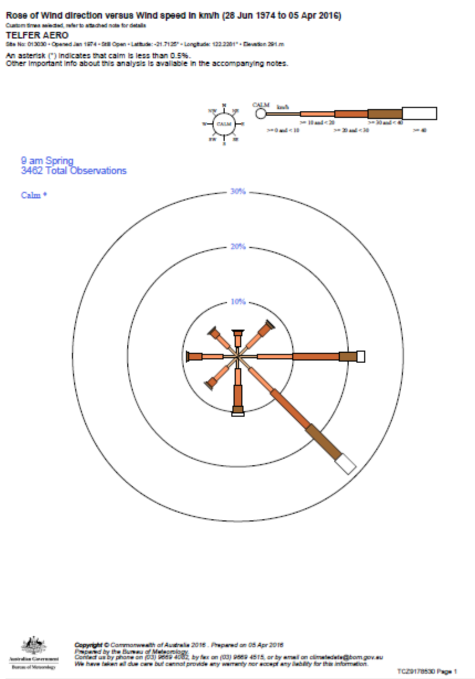
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Custom times selected, refer to attached note for details
TELFER AERO
Site No: 013030 • Opened Jan 1974 • Still Open • Latitude: -21.7125° • Longitude: 122.2281° • Elevation 291.m
An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.
CALM
km/h
>= 0 and < 10
>= 10 and < 20
>= 20 and < 30
>= 30 and < 40
>= 40
9 am Spring
3462 Total Observations
Calm *
30%
20%
10%
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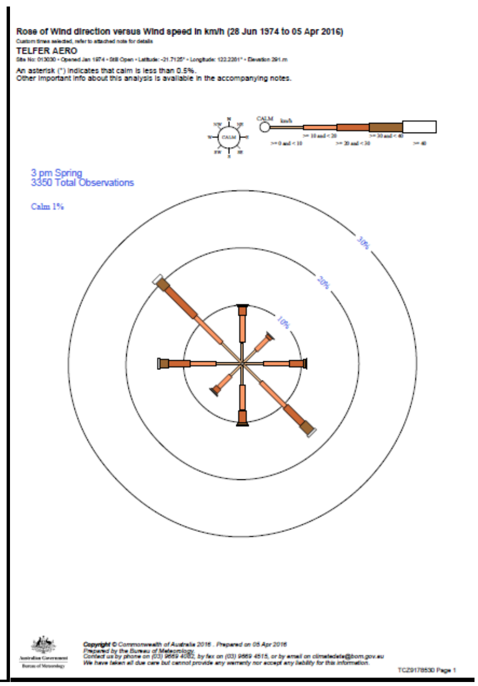
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TELFER AERO
Site No: 013030 • Opened Jan 1974 • Still Open • Latitude: -21.7125° • Longitude: 122.2281° • Elevation 291.m
An asterisk (*) indicates that calm is less than 0.5%.
Other important info about this analysis is available in the accompanying notes.
CALM
km/h
>= 0 and < 10
>= 10 and < 20
>= 20 and < 30
>= 30 and < 40
>= 40
3 pm Spring
3350 Total Observations
Calm 1%
30%
20%
10%
Copyright © Commonwealth of Australia 2016 . Prepared on 05 Apr 2016
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Appendix 2

Guiding Principles for Ecological Fire Management in Hummock Grasslands

1. Climate and vegetation make landscapes dominated by spinifex grasslands highly prone to fire. For thousands of years, lightning and human ignitions have ensured that fire is an environmental factor that has influenced the structure, function and biodiversity of spinifex grasslands.
2. Species and communities vary in their adaptations to, and reliance on fire. Knowledge of the ways in which species and communities respond to fire, and of the temporal and spatial scales of fires in relation to life histories of organisms or communities, and of traditional Aboriginal burning patters, underpins the sustainable use of fire.
3. Rainfall is a primary driver of the rate of fuel accumulation and subsequent flammability of spinifex grasslands. Large bushfires are usually preceded by seasons of above average rainfall.
4. The response of species and communities to fire will be influenced by the subsequent rainfall and by the scale and patchiness of fire, which can drive systems towards a new transient state with respect to species composition and structure.
5. Fire management is required primarily to conserve and protect biodiversity and other assets and values from damaging fire regimes.
6. Fire management should be both precautionary and adaptive, considering the requirements of both fire sensitive (habitat specific) and fire maintained communities and species in order to optimize conservation outcomes.
7. Landscapes dominated by spinifex grasslands are often vast, remote and difficult to access. Fire management resources are scarce, so proactive fire management including fire suppression and prescribed burning, should focus on areas of high value. On much of the spinifex grasslands, passive management, including allowing unplanned fires to burn, is a realistic and acceptable management option.
8. Fire diversity can support biodiversity both at landscape and local scales. At the landscape scale, a fine grain mosaic of patches of vegetation representing a range of seral (post-fire) states will provide diversity of habitats for organisms that are mobile and can move through the landscape. At the local scale, appropriate intervals between fire are necessary to ensure the persistence of sessile or less mobile organisms.
9. The scale or grain size of the mosaic should a) enable natal dispersal, b) optimize boundary habitat (boundary between two or more seral states), and c) optimize connectivity (ability of key species to migrate between seral states).
10. A combination of regular mosaic burning and strategic fuel reduced buffers will stop or buffer the mega-bushfire cycle in spinifex plains. Landsystems dominated by soft grasses (introduced or native) have the potential to burn annually or biennially following good seasons. Grazing can mitigate the bushfire threat in these landsystems.
11. All available knowledge including scientific, local and indigenous knowledge should be utilized to develop ecologically appropriate fire management.
12. Consultation and partnerships with relevant landholders, neighbours and traditional owners, is an effective way of managing fire for mutual benefit.
13. 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 prescribed fire and for mapping and monitoring fire mosaics and fire history.
14. Where spinifex grasslands have been invaded by flammable introduced species such as buffel grass, which is capable of adversely altering the frequency and intensity of fire, prescribed fire should be used conservatively and strategically to break up the run of major bushfires.

Appendix 3

A guide to predicting spinifex fire behaviour in a 6-10 year old fuel

Field Guide to Spinifex Clump Profile Fuel Moisture Content for a Class 2 (standard) fuel

1. Leaves bright green with few / no yellow leaves: Class 2 PMC ~31-40%

2. Leaves pale green with some yellow leaves: Class 2 PMC ~21-30%

3. Leaves yellow-green with many yellow leaves: Class 2 PMC ~16-20%

4. Leaves yellow / straw, no green leaves. Class 2 PMC ~12-15%

PMC correction for older fuels with a higher proportion of dead fuel (>5%)

Class 3 PMC = Class 2 PMC - (1/(0.03 x RH)) x 1.5; If Class 3 PMC = < 14%, then set Class 3 PMC to 14%
Class 4 PMC = Class 2 PMC - (1/(0.03 x RH)) x 2.5; If Class 4 PMC = < 13%, then set Class 4 PMC to 13%.
Class 5 PMC = Class 2 PMC - (1/(0.03 x RH)) x 3.5; If Class 5 PMC = < 12%, then set Class 5 PMC to 12%.

A. Use Class 2 PMC mid-point from colour photos above, or;
B. Use Class 2 PMC calculated from AWAP (section 3C).

Example 1 (Class 3 fuel):
Step 1: The colour of live spinifex clumps is yellow-green (3 above), so the PMC for a standard Class 2 fuel (little dead material) is ~16-20%, midpoint = 18% (or use PMC calculated from AWAP).
Step 2: RH = 20%.
Step 3: Now correct for the actual fuel class to be burnt; Class 3 fuel is to be burnt, so PMC correction is:
Class 3 PMC = 18 - (1/(0.03 x 20)) x 1.5
Class 3 PMC = 18 - (1.7 x 1.5) = 15.5%.
Example 2 (Class 5 fuel to be burnt):
Step 1: The colour of live spinifex is yellow / straw, (4 above), so the PMC for a standard Class 2 fuel (little dead material) is ~12-15%, midpoint = 13.5% (or use PMC calculated from AWAP).
Step 2: RH = 10%
Step 3: Now correct for actual fuel class to be burnt; Class 5 fuel is to be burnt, so PMC correction is:
Class 5 PMC = 13.5 - (1/(0.03 x 10)) x 3.5;
Class 5 PMC = 13.5 - (3.3 x 3.5) = 2.0%; Class 5 PMC = <10%, so set Class 5 PMC to 12%.

4

Fuel Structural Class 2

Mostly discrete, compact hummocks, some joined. No or few dead (black/grey) leaves or stems evident in hummocks. Spinifex flower/stalks present. Most plants 20-30 cm tall to foliage and 20-30 cm wide. Some soft grasses and herbs present. 6-10 years old depending on site and rainfall.

Cover spinifex live(%)	Cover spinifex dead(%)	Cover Other (%)	Cover fuel total (%)	Bare ground (%)	Mean clump ht (cm)	Mean fuel load (t/ha)
30-40	<5	5-10	40-50	50-60	25	5.5

	Wind speed @ 10 m open (U_{10}) and @ 1.7 m ($U_{1.7}$) (km/h) (For wind speeds > U_{10} 40, use the equations above to estimate fire behaviour) Rate of Spread (m/h) and flame height (m)							
PMC (%)	**$U_{1.7}$ <7 U_{10} (<10)**	**7 (10)**	**9 (15)**	**13 (20)**	**15 (25)**	**18 (30)**	**21 (35)**	**24 (40)**
35	0	0	0	0	0	0	0	789 2.1
30	0	0	0	0	0	697 2.1	856 2.3	1025 2.4
25	0	0	0	556 1.9	745 2.1	950 2.3	1168 2.5	1398 2.6
20	0	0	560 1.9	813 2.0	1089 2.4	1388 2.6	1706 2.8	2042 3.0
15	0	551 2.0	964 2.3	1325 2.6	1776 2.9	2263 3.1	2782 3.3	3330 3.5
12	0	805 2.2	1336 2.6	1936 2.9	2595 3.3	3307 3.5	4065 3.8	4865 4.1