Fire Diversity in a Bio-diversity Hotspot

Fire Regimes for the Conservation of Biodiversity in the South-West of Western Australia: A Concept for Discussion

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1. Context

The subdued natural landscapes of the south-west of Western Australia belie a diversity of life so remarkable that the region is now recognised as one of the world's twenty five hotspots of mega-biodiversity – the only one in Australia. It is primarily the great diversity and endemism of plants that has earned the region this recognition.

Flammable vegetation and hot, dry summers have ensured that fire is a natural environmental factor, which together with climate, landform and soils, has operated over thousands of years to forge this biodiversity. Prior to European settlement, fires were started by lightning but more frequently they were set by Noongar Aboriginal people who used fire with confidence, purpose and skill for a myriad of reasons. To Noongar people, fire was not a threat to be feared, fought and conquered, but a friend and a tool with which to manage and manipulate the landscape so that it provided the physical and spiritual necessities of life. Plants, animals and ecosystems have evolved in this fire prone-environment and have developed a range of physical and behavioural traits that enable them to persist with, and in some cases, depend upon a variety of fire regimes.

For many plant species, reproduction and regeneration are cued or enhanced by fire and for many plant communities, particular fire regimes are necessary for the maintenance of floristic and structural diversity. A particular sequence and scale of fires are necessary to provide habitat diversity and opportunity for animals. However, the way in which species and communities respond to fire is variable. Some assemblages are quite resilient to frequent fire and recover to their pre-fire state relatively quickly, while others are more sensitive to fire and can take many decades to recover. Thus, no fire regime, or history of fire interval, season, intensity, patchiness and scale is optimal for all species and communities and although fire diversity can promote biodiversity, some fire regimes can also threaten biodiversity.

The damage potential and difficulty of suppression of a bushfire is determined by the amount of vegetation that burns, its moisture content and the weather conditions. Unlike the Serangetti Plains of Africa, the south-west bushland does not have vast herds of roaming herbivores munching and mowing their way through the vegetation. Instead, live and dead vegetation accumulates in the absence of fire. Prior to European settlement, burning by Noongar people maintained a patchwork-quilt of vegetation at different stages of post-fire development (pyric stages) – from recently burnt patches to long unburnt patches. This fire mosaic contained the spread and intensity of wildfires. Very large and intense wildfires were not in the best interests of Aboriginal people and were probably rare events. Imagine the difficulty of survival in a landscape blackened over tens of thousands of hectares? In many parts of Australia where traditional indigenous fire management has ceased and anthropocentric fire has been excluded, it is common for the once domesticated fire regime to become feral. Feral fire regimes are characterised by infrequent, large and intense wildfires that cause substantial environmental, social and economic damage.

Today, in fragmented, urbanised and settled landscapes, wildfires can threaten people, property and conservation values. The rapidly expanding rural-urban interface is most vulnerable, but even beyond this, wildfires threaten rural towns, farms and other infrastructure. The job of fire management in regional areas, including containing bushfires, falls largely to volunteers and to professional fire fighters from the Department of Conservation and Land Management (CALM) and the Fire and Emergency Services (FESA).

On lands managed by CALM, the primary aim is to manage fire to conserve biodiversity and to ensure an acceptable level of protection to human life and property. Fire management is complex and potentially dangerous and requires the skilful combination of art and science. Fire science, including fire behaviour and ecological effects of fire on natural ecosystems, has advanced as a result of on-going research undertaken by a range of organizations over the last 40 years or so. Although our knowledge is incomplete, fire management must be underpinned by fire science. A symposium which synthesised our scientific understanding of fire in south-west ecosystems was held in Perth in April 2002. The scientific proceedings of this symposium will soon be published as a book comprising some twenty chapters written by fire managers and scientists who are recognised experts in their particular field. This collation and synthesis of the latest fire science has provided an opportunity for CALM to further develop and adapt its fire management. From the fire symposium, and drawing on the experiences of other agencies, especially Parks Victoria, a revised fire management framework based on the following twelve key scientific principles is being developed.

2. Key Scientific Principles

Principle 1:

The vegetation and climate of the south-west region make it highly prone to bushfire. Fire is an environmental factor that has and will continue to influence the nature of south-west landscapes and biodiversity and fire management is integral to conservation and land management.

Principle 2

Species and communities vary in their response to, and reliance on, fire. Knowledge of the temporal and spatial scales of fires in relation to the life histories of organisms or communities involved underpins the use of fire in natural ecosystems.

Principle 3

Following fire, environmental factors such as landform, topography and species' life history attributes, and random events such as climatic events, often drive ecosystems towards a new transient state with respect to species composition and structure. This may preclude the identification of changes specifically attributable to fire.

Principle 4

Fire management is required for two primary reasons, which are not necessarily mutually exclusive: a) to protect and conserve biodiversity and b) to reduce the occurrence of large, damaging wildfires. The biological impact (killing power) and suppression difficulty of a single fire event and the rate of recovery are directly proportional to the intensity and size of the fire.

Principle 5

Fire management should be precautionary and consider both ecological and protection objectives in order to optimise outcomes.

Principle 6

Fire diversity promotes biodiversity. An interlocking mosaic of patches of vegetation representing a range of biologically-derived fire frequencies, intervals, seasons, intensities and scales need to be incorporated into ecologically-based fire regimes if they are to optimise the conservation of biodiversity at the landscape scale.

Principle 7

Avoid applying the same fire regime over large areas for long periods of time and avoid seral and structural homogenisation by not treating large areas with extreme regimes such as very frequent or very infrequent fire intervals.

Principle 8

The scale, or grain-size, of the fire-induced mosaic should a) enable natal dispersal b) optimise boundary habitat (interface between two or more seral states) and c) optimise connectivity (ability of fauna to cross).

Principle 9

All available knowledge, including life histories, vital attributes of the flora and fauna and knowledge of Noongar fire regimes should be utilised to develop ecologically-based fire regimes for a landscape unit or a vegetation complex.

Principle 10

Fire history, vegetation complexes and landscape units should be used to develop known and ideal fire age class distributions.

Principle 11

Wildfire can damage and destroy both conservation and societal values, hence risk management must be based on a systematic and structured approach to identifying and managing the consequences of such an event.

Principle 12

Fire management should adapt to changing community expectations and to new knowledge gained through research, monitoring and experience.

Setting fire management objectives

Setting clear, workable and measurable biodiversity conservation objectives is not straight forward because of the complexity of biodiversity through space and time and because knowledge of biodiversity and disturbance ecology, including fire, is incomplete. Notwithstanding this, having clear fire management objectives for the conservation of biodiversity is of key strategic importance. It will assist with developing fire management plans and standards, with determining strategies and tactics and with assessing the acceptability or otherwise of the environmental impacts of fire as they are understood from research and monitoring.

An important strategic issue for CALM is the extent to which perceived wildfire threat to human life and property over-ride biodiversity conservation objectives. One approach being considered by the Department is to develop fire regimes that aim to conserve biodiversity, then carry out a systematic wildfire risk analysis to determine the threat posed by these regimes to life and property values. Fire management can then be modified where the risk or threat of wildfire, and consequent damage, is deemed unacceptable.

The following is a proposed hierarchical or nested set of broad fire management objectives and strategies that attempts to encapsulate the spatial and temporal scales important for maintaining biodiversity. Not all biodiversity can be conserved all of the time everywhere. Setting objectives for different scales of space and time reflects the reality and that is of ecosystems that are dynamic and ever-changing, rather than static and fixed in space and time.

At the Bioregional scale

The Australian environment has been divided into 80 broad biogeographic regions, which provide a framework for the development of a national reserve system and other natural resource management decisions. A bioregion is a large geographic area that is similar with respect to climate, geology, landforms, broad vegetation types, flora and fauna and land use. There are seven bioregions in the south-west region of Western Australia ranging in area from about fifteen thousand square km to ninety thousand sq km.

Bioregion fire management objectives:

- To conserve the biodiversity of the bioregion whilst providing a sufficient level of protection to fire sensitive ecosystems and to societal values.

Broad strategies to achieve this:

- Maintain a mosaic of interlocking patches representing a diversity of fire regimes at appropriate temporal and spatial scales.
- Undertake a wildfire risk analysis with respect to the threat posed to fire sensitive species and communities and to life and property.
- Take measures, including the use of prescribed fire to reduce fuels, mechanical modification of fuel, early detection and suppression, to ameliorate unacceptable risks.
- Where prescribed fire is used, this can be incorporated into the mosaic.
- Wildfires will form part of the mosaic.
- Continually adapt management with new knowledge gained from research, monitoring & experience.

At the Landscape scale

There are likely to be many landscapes within a bioregion. A landscape can be conceptualised (and mapped) as being a mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometres-wide area within a bioregion. Several attributes, including weather, landforms, soil types, assemblages of local flora and fauna and disturbance regimes tend to be similar and repeated across the area. Landscapes may vary from several thousand ha to tens of thousands of ha. Mattiske & Havel have recently defined landscapes within the RFA region.

Landscape scale objectives:

- Maintenance of fire diversity and hence biodiversity, through space and time.
- Maintenance of a diverse representation of ecosystem structures, seral states and habitats through space and time.

- Protection of relatively fire sensitive ecosystems and niches such as riparian zones, aquatic ecosystems, some wetlands, peat swamps, some valley floors, monadnocks, rock outcrops, steep south-facing aspects, other non-forested complexes and new growth forests from frequent fire or large and intense wildfire. Fire sensitive ecosystems are usually characterised as those that contain plant species that are obligate seeders with long juvenile periods, fauna that are habitat-specific, sessile and prefer late mature or mid-late successional stage vegetation, communities that take a relatively long time to recover to their pre-fire state, vegetation types that are relatively inflammable because they either stay wetter for longer or have sparse ground fuels.

<u>Broad strategies to achieve these</u>:

- Maintaining an interlocking mosaic of patches of vegetation at different seral states including recently burnt and long unburnt states, and patches burnt in different seasons. The mosaic should have at least three biologically significant phases, being a) time since last fire, b) fire frequency and c) fire season. Phases should be determined from knowledge of the fire ecology/life histories of the most fire sensitive taxa within the landscape.

- Reducing the likelihood of events such as large-scale intense and damaging wildfires by incorporating risk mitigation strategies such as fuel reduction, fire detection and suppression into the overall mosaic.

- Using vital attributes of plants and animals such as juvenile period (age to first flowering) of plants that depend on seed for regeneration after fire (obligate seeders), the life span of serotinous species (obligate seeders with seed stored in woody capsules in the canopy), habitat requirements of key fauna (especially fauna that require mature, late successional state vegetation and rare and endangered taxa) to estimate the range of desirable seral states (time since last fire) and fire frequencies within a landscape.

- Favouring small to medium fire management units (not burnt patch size) within the range 500-5 000 ha. Scale, grain size or patch size of the mosaic is important in determining boundary habitat (or area of edge effect or interface between different seral states) and connectivity (dispersal and hence recolonisation). There may need to be a trade-off with what is practical and cost effective to implement.

- Incorporate wildfires in the mosaic, but limit their size and frequency.

- Ensure that the mosaic is dynamic by applying a variable fire regime to a fire management unit (see below for definition) to promote temporal and spatial variation. Avoid linking units of similar post-fire state and avoid repetitious fire treatment on a patch.

- Retain protectable, manageable & representative "no planned burn" scientific reference areas where possible as part of the mosaic.

At the Fire Management Unit scale

A fire management unit is a spatial element within a landscape unit. It could be a (sub) catchment or a mapped management boundary, such as a forest block - it could contain a representation of landforms and ecosystems and vegetation complexes (Mattiske & Havel

1998) common to the landscape unit. Fire management units can be sinks or sources of recolonisation and can vary in size from a few hundred hectares to a few thousand hectares.

Fire management unit scale objectives:

- Conservation of biodiversity through time.
- Diverse and dynamic fire regime in season, frequency and interval of fire
- Provision of a variety of habitats, seral states and structures through time.
- Protection of soils.
- Protection of ecologically sensitive areas and niches such as riparian zones, aquatic ecosystems, wetlands, granite outcrops, other non-forested complexes and new growth forests from frequent fire or large and intense wildfire

Broad strategies to achieve these:

- Vary the fire regime applied to a fire management unit. Vary the season, frequency and interval of fire based on vital attributes and life histories of key taxa (fire sensitive taxa).
- Implement mostly patchy burns with occasional near complete burn. That is, create patchiness within patches (an intra-patch mosaic). Burn patchiness and protection of fire sensitive habitats is best achieved by low intensity fire under moist conditions.
- Burn flammable, drier habitats at intervals ranging from frequent to infrequent, based on vital attributes and life histories of key taxa (see Burrows and Friend 1998).
- Burn less flammable (fire sensitive) habitats (eg riparian zones, some swamps, valley floors, granite outcrops) less frequently, the interval to determined by vital attributes and life histories of key taxa.
- Apply moderate intensity fires under dry conditions infrequently (see Burrows and Friend 1998). These may have severe acute (short term) impacts, but are vital for promoting regeneration of many obligate and facultative seed species and associated habitats (eg thicket structures).
- Permit/accept occasional wildfires as they are an important part of the fire diversity

Threatened Species and Communities

Various State and Federal legislation impose requirements in relation to how fire management activities are conducted with respect to threatened taxa. Threatened species and communities will be protected/enhanced by devising and implementing fire regimes that ensure survival and reproduction of these taxa (where the fire ecology of threatened taxa is well understood, for example, the Tammar and some plant species), or will protect taxa from fire regimes that are known to or are likely to cause the decline of these taxa. Threatening fire regimes may include long periods of fire exclusion, sustained frequent burning, large and intense wildfires and post-fire grazing. Where no fire ecology information exists for a threatened species, then carefully monitored experimental burning under dry conditions in autumn might be considered. No discrete/isolated or sole population should be impacted upon by a single fire event where the consequences of fire are unknown.

Planning Considerations

Planning to achieve the objectives outlined above should commence at the landscape scale and because of the complexity of planning information should be undertaken in a GIS environment. The first task is to define and map biologically meaningful landscape units based on biophysical elements, such as geology, climate and vegetation complexes. Mattiske & Havel (2002) working under contract to DCLM, have delineated "Landscape Conservation Units in the south-west forest region of WA.

Tasks – At the Fire Management Unit scale (FMU):

1. Map the vegetation complexes (e.g., Mattiske and Havel 1998) or ecosystems and link the biophysical and fire response data tables to the mapped veg. complexes. Characterise the fire-proneness and fire sensitivity of each vegetation complex based on the above information. Rate fire-proneness as Low, Medium or High.
2. For each vegetation complex, generate an actual known vascular flora and vertebrate fauna species list and a predicted species list (data source: e.g., Herbarium, Havel thesis, Burrows fire response, Museum records, Wildlife Branch, Christensen FDIS).
3. From these lists identify 'fire sensitive' taxa – i.e., fire sensitive plants are obligate seeders, especially serotinous sp., with long juvenile periods, and fire sensitive vertebrate fauna are those with specialised habitats, that require mature late successional state vegetation, exist as metapopulations, have low dispersal capacity, low fecundity and are prone to predation. Plot the location of these taxa if known, or infer link with veg. complex. Plot locations of DRF and threatened fauna. Link to fire response database. Generate rey (data source: Museum records, Christensen system) .
4. For fire sensitive plants, determine juvenile period (*jp*) and life span (*ls*) (source: Burrows fire response database). If *jp* is unknown, assume:

Rainfall (mm)	Veg Complex fire prone class	*jp*
900+	L M H	3 4 6
750-900	L M H	4 5 7
500-750	L M H	5 6 8

5. For the same fire sensitive plants, determine life span (*ls*). If *ls* is unknown assume it is 7(*jp*) for understorey plants and 10(*jp*) for overstorey trees.
6. *jp* and *ls* are used to help set minimum and maximum fire intervals for each vegetation complex.
7. Fire season variability: We know that late summer/early autumn fires optimise regeneration and survival from seed in Mediterranean ecosystems (see Burrows and Wardell-Johnson *in press*). We also know that the fire severity, killing power and homogeneity (% landscape burnout) is proportional to fuel dryness and fuel quantity so frequent summer/autumn fires are undesirable unless the frequency is such that the fires are low intensity (e.g., every 3-4 yrs).
8. In any FMU, there will be a variety of interlocking vegetation complexes and associated habitats with different fire response patterns so will require different fire regimes to conserve biodiversity. Consolidate/group veg. complexes with similar fire responses (see above). For each FMU, devise a standard ecological fire regime for the most fire-prone (fire resilient) vegetation complex to maintain that complex and to protect less fire prone complexes (and other values) in and around the FMU. Within a block, there is likely to be at least 2 broad habitat types that require different fire regimes. The drier, more flammable uplands will generally contain flora species that are mostly resprouters and have relatively short juvenile periods and fauna that do not require mature or medium to late successional state vegetation. The lowlands, creeks, swamps etc. will generally contain flora that are fire sensitive with relatively long juvenile periods and fauna that prefer mature, medium to late successional stages of vegetation. Moisture differentials across the block (between broad habitat types) can be exploited to differentiate fire regimes applied to flammable and less flammable habitats within the block.
9. Implementing this fire regime whilst protecting other more sensitive vegetation complexes and habitats from frequent fire will require exploiting natural seasonal factors,

natural fire barriers and landscape variation in moisture (flammability) differentials. The variability of the flammability of the landscape is greatest in spring and least in autumn before the opening rains.

10. A proposed standard ecological fire regime that incorporates variation in fire interval and season is:
    - Year 0: Patchy spring burn (60-80% burnout flammable (fire resilient) complexes, <5% burnout least flammable (fire sensitive) complexes.
    - Year 2(*jp*): As above
    - Year 4(*jp*): As above
    - Year 5(*jp*): Late summer/early dry season burn. 90% + burnout of FMU.
    - Year 8-10(jp): Return to spring burn

11. Ecological attributes of the standard ecological fire regimes

Two cycles of low intensity, patchy fires under moist spring conditions to burn the uplands and ridges only (the fire resilient or most flammable components of the landscape - avoid burning lowland or fire sensitive habitats such as granite outcrops etc), followed by a burn under dry soil conditions in autumn to burn the entire landscape. The interval between the spring burns should be twice the juvenile period (*2jp*) of the slowest maturing fire sensitive understorey species on upland/ridge vegetation units. This is to allow for replenishment of seed banks. For example, this will be 6-8 years for most drier vegetation complexes in jarrah and karri forest and is termed the sustainable fire interval. The interval between the second spring burn and the next autumn burn should be at about the juvenile period of the slowest maturing species on the uplands – that is, about 3-4 years for jarrah forests. Following the autumn burn, fire should be excluded from the management unit/block for a time equivalent to 1.5 – 2 times the sustainable fire interval, or 9-16 years for jarrah forests. The time interval can vary to provide the flexibility to ensure representation of a range of older seral states within the landscape. The extended fire-free interval following the autumn whole-of-landscape burn will also allow replenishment of seedbanks, the establishment of germinants, development of mature seral states (habitats) and the completion of life cycles of short-lived leguminous species. The next burn after this period should be a low intensity spring burn under moist conditions and be restricted to drier upland habitats, returning to the cycle. This will ensure that fire sensitive habitats (lowlands, swamps, creek lines, granite outcrops etc.) are burnt infrequently (every 24-30 years) to regenerate the habitat (important where the above fauna occur) and to allow a replenishment of the seedbank. Check that this fire free period a) caters for the juvenile period of the slowest maturing species occurring on the block, b) caters for the habitat requirements of the fire sensitive fauna and c) is within the reproductive life cycle of the shortest lived fire sensitive serotinous species. If not, then the inter-fire period will need to be extended or shortened, whatever the case may be.

It is important to ensure that vegetation associations (species or structures) that depend upon, or are favoured by fire for reproduction, are burnt before plants reach the end of their reproductive life, or lose the capacity to regenerate following fire. Species that are relatively short lived, are obligate seeders and that store seed in woody capsules (serotinous) are particularly vulnerable to long periods of fire exclusion (key fire response indicators, eg., *Banksia seminuda, Melaleuca viminea*). These species have no capacity to store seed on site once the parent plant dies and the seed has been shed – the seed of these species, if it does not regenerate, deteriorates rapidly once shed. Long periods of fire exclusion may also reduce the capacity of thicket-forming species to form thickets, which are important in their own right, and may be important habitat for some fauna (eg., Tammar, Quokka, Quenda). The longevity of soil-stored seed is largely unknown.

Checks:

- Is this regime compatible with DRF, threatened fauna, fire sensitive fauna, threatened ecological communities etc.?

- Is the maximum and minimum interval between fire within the *jp* and *ls* range of fire sensitive taxa for each vegetation complex?

Planning the Landscape Scale Mosaic

1. Identify representative No Planned Burn (NPBs) areas –and other areas that should not be burnt. NPBs ideally should be representative of vegetation complexes in the Landscape unit and be no larger than about 500 ha.
2. Identify other complexes or circumstances that may require deviation from the standard ecological fire regime – silvics, research plots, etc.
3. Carry out risk analysis to identify other areas that needs to be protected from fire as a matter of high priority – including regeneration, infrastructure, life and property values etc. Devise appropriate fire management for these areas – could be regular fuel reduction regime.
4. For each landscape unit, implementing a mosaic of interlocking FMUs with different fire histories will require a desk top GIS exercise, of "juggling" the regimes applied to the FMUs and running various scenarios to test/ensure that the mosaic is consistent with the principles described above. Because of the complexity of the exercise, involving space and time, it is most efficiently achieved using a GIS. Run the standard fire regime through each FMU starting with where the FMU is already with respect to the cycle. Set some rules such that the time since last fire at the boundaries of FMUs >j but <=3j, ensure that high fuel accumulation cycles are disconnected, optimise spatial arrangement of cells (FMUs) of various fire histories. Once satisfied that the conditions of the mosaic are met in time and space, this then forms the base fire management plan to conserve biodiversity for that landscape unit. The plan will need to be reviewed at some interval (3 yrs?) to incorporate changes, logging, wildfire etc.
5. Every three yrs, generate frequency distributions showing FMUs with time since fire, and vegetation complexes with time since fire for each landscape unit.

Monitoring

Extend FORESTCHECK to include fire response monitoring. Aim to establish monitoring sites in a set of representative veg complexes, including NPBs as reference areas.