Fire Regimes for the Conservation of Biodiversity in South-West Forest Ecosystems: A Planning Framework

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Context

Fire is a natural environmental factor, which together with climate and geomorphology, has operated over many thousands of years to shape the biodiversity of south-west forests and associated non-forest ecosystems. Communities and organisms have evolved in this fire prone-environment and have therefore adapted to, and in some cases, depend upon, a variety of fire regimes for their continued existence. Forest fires can be as diverse as the environment in which they occur and over millennia have varied in frequency, season, intensity, scale and patchiness. No single fire regime is optimal for all organisms at any scale. Fire diversity can promote biodiversity at the landscape scale, but some fire regimes can reduce biodiversity.

Unplanned forest fires, or bushfires, have and will continue to occur as a result of negligence, arson or lightning. Bushfires can threaten conservation values, people, property and forest products. It is the responsibility of land owners to take reasonable measures to reduce the risk of death or property damage to neighbouring land owners. Therefore, fire management is necessary to a) protect and maintain biodiversity and b) to reduce the negative impacts of bush fires on societal values. These objectives are not necessarily mutually exclusive.

This paper provides a framework for discussion of forest fire management in south-west WA to achieve desirable conservation and community protection outcomes.

Key Scientific Principles

This framework is based on the following scientific principles (adapted from Burrows and Friend, 1994 and Fire Ecology Working Group, Parks Victoria 1999).

Principle 1

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

Principle 2

Species and communities vary in their adaptations 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 resource management.

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 the biota and b) to reduce the occurrence of large, damaging wildfires. The biological impact 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 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 mosaic should a) enable natal dispersal of key indicator species 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.

Whole-of-Forest Scale of Fire Management

The maintenance of biodiversity and of the ecological processes upon which it depends is fundamental to the principle of ecologically sustainable forest management (ESFM). Setting forest 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 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.

The following is a proposed hierarchical set of fire management conservation objectives for forests. This attempts to encapsulate the spatial and temporal scales important for maintaining biodiversity. In this paper, forest ecosystems include all ecosystems embedded within the matrix of the south-west forest region. It could be argued that some of these objectives described below are actually strategies. An important strategic issue for the Department is the extent to which conservation objectives over-ride other societal values and what level of risk is acceptable. This is best dealt with by a systematic and soundly-based risk assessment process.

Objective:

Protect and promote the biodiversity of forest ecosystems and processes upon which it depends whilst providing a sufficient level of protection to fire sensitive ecosystems and to societal values.

Strategies:

Using the best available knowledge, maintain a mosaic of interlocking patches representing a diversity of fire regimes. Undertake a wildfire risk analysis with respect to the threat posed to fire sensitive values. Take measures, including the use of prescribed fire to reduce fuels and early detection and suppression to ameliorate unacceptable risks. Where prescribed fire is used, this can be incorporated into the mosaic. Bushfires will form part of the mosaic. Continually adapt management with new knowledge gained from research, monitoring & experience.

Landscape Scale of Fire Management

A concept of a landscape adopted here:

> *"A mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometres-wide area. Several attributes, including geology, soil types, vegetation types, local faunas, climate and natural disturbance regimes tend to be similar and repeated across the whole area"* (Forman 1995).
>
> Bio-physically-based amalgamations of the Mattiske & Havel (1998) vegetation complexes form a basis for identifying landscape units. These are referred to here as Forest Landscape Units

Objectives:

- *Maintenance of fire diversity and hence biodiversity, through space and time.*
- *Maintenance of a diverse representation of forest structures, seral states and habitats through space and time.*
- *Protection of ecologically sensitive areas and niches such as riparian zones, aquatic ecosystems, wetlands, granite outcrops, steep south-facing aspects, other non-forested complexes and new growth forests from frequent fire or large and intense wildfire.*

Strategies:

- Maintain 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; these being a) time since last fire, b) fire frequency and c) fire season.

- Reduce the likelihood of events such as large-scale intense and damaging bushfires by incorporating risk mitigation strategies such as fuel reduction into the overall mosaic.

- Use biological indicators/vital attributes such as juvenile period of obligate seeders, longevity of serotinous species (obligate seeders with seed stored 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.

- Manage fire so that the proportion of the landscape unit (or vegetation complex) at each seral stage takes the form of a negative exponential with parameters set by biological indicators (see details for calculating this below).

- Favour small to medium prescribed burn patch sizes within the range 500-5 000 ha. Smaller burns risk adverse herbivory impacts. Larger burns risk delayed recolonisation and potential isolation of some habitats for a longer time. The larger the burn, the greater should be the proportion of internal patchiness. Scale, grain size or patch size of the mosaic is important in determining boundary habitat (or area of edge effect) and connectivity (dispersal and hence recolonisation). If necessary, trade this off with what is practical, safe and cost effective to implement.

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

- Ensure that the mosaic is fluid by applying a variable fire regime to a patch to promote temporal and spatial variation. Avoid linking patches 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.

Forest Patch (block) Scale of Fire Management

A concept of a 'forest patch' adopted here:

A spatial element within a landscape. A relatively homogenous (seral state) non-linear area that differs from its surroundings. 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 common to the landscape unit. Patches can be sinks or sources for recolonisation . Patches can vary in size from a few hundred hectares to a few thousand hectares.

Objectives:

- *Maintenance of biodiversity through time.*
- *Provision of a variety of habitats, seral states and forest 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 bushfire*

Strategies:

- Vary the fire regime applied to a patch. Vary the season, frequency and interval of fire based on vital attributes and life histories of key 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 (fire resilient), 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) wetter habitats (eg riparian zones, some swamps, valley floors, granite outcrops, wet forest sites) less frequently, the interval to be determined by vital attributes and life histories of key taxa.
- Apply moderate intensity fires under dry conditions infrequently (see Burrows and Friend 1998).
- Permit 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. For many listed taxa, there are specific recovery plans that specify fire management appropriate to these taxa. Where there is no knowledge of fire ecology, adopt the precautionary principle.

Planning Considerations

Planning should commence at the forest landscape scale and should be undertaken in a GIS environment. The first task is to define and map landscape units based on biophysical elements, such as geology and climate. The Mattiske & Havel (1998) vegetation complexes form a sound basis for defining forest landscape units.

Tasks – Landscape scale:

1. Map and determine the area of the landscape unit. Map and determine the area of key vegetation complexes within the unit (Mattiske and Havel 1998).

2. Identify (label) and map patches within the landscape unit (see definition of patch above).

3. Determine the actual extent of seral states (time since last fire) by a) vegetation complex and b) patch. Graph or tabulate this showing the area (ha) on the '*y*' axis and seral state (time since last fire – in 2 yo age classes) on the '*x*' axis.

4. Determine the 'ideal' range and distribution of seral stages (time since last fire) within a landscape unit by a) vegetation complex and b) patch. The 'ideal' age-class distribution is based on (global) observations that where fires are allowed to burn naturally, then the age-class distribution approaches a negative exponential. This may or may not be 'ideal' for local ecosystems, but is a useful starting point. See instructions at Appendix 1 for calculating 'ideal' distribution of seral states within a vegetation complex or landscape unit.

5. Compare the actual and ideal extent of seral states for a) vegetation complexes and b) patches.

6. Identify patches and vegetation complexes that are over-represented or under-represented in the various age classes and develop a burning program to correct this.

7. From fire history records, identify and map patches that have a) been repeatedly burnt in spring burn and b) have been burnt in summer or autumn in the last 20 years or so.

Tasks

For each patch (identified above) within a landscape unit;

1. Collate life history and vital attributes information for the constituent vascular flora. This is done by:

    - Generating a species list for the patch using Herbarium databases.
    - Identify and list species that are killed by fire and that depend upon seed for regeneration (obligate seeders). Use the Fire Response database (FIREBASE - Burrows), or DESCAT (Herbarium), field observations or local knowledge.
    - Determine the juvenile period (age to first flowering) and longevity of this subset of species using FIREBASE. Rank according to juvenile period.
    - Determine the broad habitat type, or general location of the top 10% slowest maturing (longest juvenile period) – ie, which part of the topography – midslope, plateau, creek, swamp, valley floor, granite outcrop, a particular Mattiske & Havel vegetation complex etc.
    - Map the location of these onto the patch, or colour the habitat in which these are known or likely to occur.

2. Determine the minimum fire interval for the broad habitat types in a patch based on the juvenile period of the slowest maturing plant. Determine the maximum fire interval based on the shortest life cycle of serotinous species (those that depend on canopy stored seed for regeneration). These will mostly occur in less fire prone areas such as along creeks, swamps, granite outcrops, lowlands, areas of naturally low ground fuels (sparsely treed)., Assume a maximum fire interval of 30 years where this is unknown.

3. Collate the life history and vital attributes information for the constituent mammal fauna. This is done by:

    - Generating a list of mammals for the patch – Using museum records, data held by Wildlife Branch, FDIS, or local knowledge.
    - Identify those taxa that have special habitat requirements, especially those that require mature (long unburnt) vegetation, those that occupy special niches – eg, Tammar, Quenda, Quokka, Mardo, Honey Possum – there may be others (see FDIS).

4. Determine the ecological fire management for the patch. Within a patch, 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 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 differential across the landscape can be exploited to differentiate fire regimes applied to flammable and less flammable habitats.

5. Plan for each patch, the following regime. Two cycles of low intensity, patchy fires under moist spring conditions to burn the uplands and ridges only, 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 of the slowest maturing understorey species. In most cases, this will be 6-8 years (for uplands). The interval between the second (last) last 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. Following the autumn burn, fire should be excluded from the patch for a time equivalent to 1.5 – 2 times the juvenile period of the slowest maturing upland species (9-16 years). The time interval can vary to provide the flexibility to ensure representation of a range of older seral states within the landscape. This extended fire interval following the autumn 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 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 patch, 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 interfire period will need to be extended or shortened, whatever the case may be.

Planning the mosaic

For each landscape unit, implementing a mosaic of interlocking patches at different seral states will require a desk top exercise, of "juggling" the regimes applied to the patches 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. 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.

Risk Analysis

Overlay other values, including property, new growth forest, threatened taxa etc. and carry out a systematic risk analysis. Where the risk of wildfire threat exceeds thresholds of acceptability (and this may come down to a value judgement) then modify the base plan and develop and test other iterations. Actions such as fuel reduction burns applied to reduce risk to acceptable levels, and silvicultural burns in multiple use forests are appropriate components of the mosaic. Wildfires will impinge on the plan, so the iterations and planned regimes may have to be re-done to take account of any unplanned ignitions. This planning process is adaptive management so is ongoing and responsive to wildfires and the latest information.

Appendix 1 – Determining the 'ideal' mosaic of seral states

- Planning will require a GIS, utilising available biophysical databases, information systems and expert knowledge.

- Fire interval and season affect structural diversity, habitat diversity and determine the likely presence/absence and abundance of plant and animal species. For example, if the minimum fire interval is less than the juvenile period of the slowest maturing, fire sensitive plant species, then that species (key fire response indicator) is likely to decline. This sets the minimum or lower tolerable fire interval.

- 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.

- Knowledge of the life histories of plant species is of course incomplete, but information is available for about 500 species. FIREBASE, WABIOTA, DESCAT and databases held by Wildlife Branch are accessible sources of information. Further information can be obtained by seeking out data/observations from other knowledgeable people or by a field inspection of some longer unburnt areas. For example, we know that *Melaleuca viminea*, a fire sensitive, serotinous species that occupies broad valley floors in the eastern jarrah forest, commences flowering at about age 6-8 years and lives for about 50 years. Therefore, the appropriate upper and lower interfire period for this vegetation complex is 8-50 years.

- Before attempting to define the idealised (fire) age class distribution for a vegetation type or complex, we must define the *fire cycle*. Tolhurst (2000). defines this as "*the period of time within which an area equal to the total area of the vegetation unit will be burnt*". If patterns of ignitions and fire spread were random, then it is likely that some areas would be burnt more than once within a fire cycle and some areas would remain unburnt within the fire cycle. Tolhurst defines the length of the *fire cycle* as the mid-point between the upper and lower tolerable interfire period, eg., for broad valley floors dominated by *M. viminea*, the fire cycle is estimated at 30 years.

- The ideal fire age class distribution for a particular vegetation type is not likely to be found in nature. A widely accepted model, or guide to this distribution is the negative exponential distribution (Tolhurst 2000, M. Gill pers. comm.). Tolhurst provides a means of defining the shape of this distribution. This is done by first determining the starting and finishing areas in the distribution and then using exponential regression model to determine the parameters of the curve by joining these two limits. However, this topic requires specific development for south-west WA ecosystems and will be done by the Science Division.

Model inputs/definitions:

Variable (a) = Total area of a ***vegetation community*** within a defined ***landscape unit***. In the absence of better information (clearer definition or mapping of vegetation units), the vegetation complexes of Mattiske and Havel (1998) can be used to represent vegetation communities. Forest Landscape Units are currently being defined and mapped and represent amalgamations of Mattiske & Havel vegetation complexes.

Variable (m) = Maximum tolerable interfire period to maintain all species in that vegetation complex (eg., 50 yrs for *M. viminea thickest – in the absence of data, this is probably a reasonable figure to apply to other communities*).
Variable (p) = Planning period to be used for group size in age class (time since fire) distribution histogram (eg., if p = 2 yrs, then age classes are at 2 yr intervals).
Variable (c) = Duration of fire cycle (eg., 30 yrs for *M. viminea*).

Calculations (Tolhurst 2000):

1) Area to be burnt in the first planning period: ***f*** = **p** x **a/c**
2) Area to be burned in the final planning period: ***l*** = **p**{(**c/m**) x (**a/m**)}
3) Decay constant **(k)** and coefficient **(b)** of the exponential equation describing the age class distribution of the veg. These parameters calculated using an exponential regression analysis tool and the two data points: ***f*** at time **p**/2, and ***l*** at time **m**. (This can be done in Excel).

Once theses parameters have been determined, the area **(a)** for each time interval **(t)** between time zero and the maximum tolerable fire interval can be calculated using the equation:

4) $\mathbf{a_t = b\ exp^{-(kt)}}$

No area should be available for reburning until it has passed the minimum tolerable fire frequency for the community as determined by the juvenile period of the slowest maturing, serotinous species (the key fire response indicator).

The age class distribution should be truncated at the maximum tolerable fire interval for the community as determined by the longevity of the shortest lived, serotinous species.

I suggest we take a couple of examples within a Landscape Unit and do a desk-top calculation and mapping exercise to map the "ideal" fire age class distribution for a particular vegetation complex or landscape unit. In most cases, we are likely to get a variety of veg complexes within a burn boundary, so the planning/process gets a little more complicated.

Reference: Tolhurst, K (2000). Guidelines for ecological burning in the foothill forests of Victoria. A report prepared for DNRE Vic.