FIRE-INDUCED HABITAT MOSAICS IN SOUTH-WEST LANDSCAPES
THE FIRE MOSAIC PROJECT

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Summary

Fire management based on sound science is fundamental to the conservation of biodiversity and the protection of life and property in south-west WA. There is a substantial body of scientific evidence that, within ecologically circumscribed parameters, fire diversity can benefit biodiversity at the landscape scale. We hypothesise that a fine-grained mosaic of patches of vegetation representing a range of biologically-derived fire frequencies, seasons and intensities will provide diverse habitat opportunities and can also contribute to reducing the occurrence of large, damaging and homogenizing wildfires.

The Fire Mosaic Project is an example of science-based adaptive ecosystem management to improve fire management and biodiversity outcomes. It is a collaborative landscape-scale operational trial involving staff from the Department's Science Division, Frankland District, South Coast Region, Warren Region, Fire Management Services, University of Queensland and University of Western Australia. The project aims to determine whether a) a fine-grained fire mosaic can be created by the frequent and targeted introduction of fire into the landscape (patch-burning) and b) this enhances biodiversity conservation through space and time. This does not mean frequently burning out the landscape, but rather, attempting to create a mosaic by regularly burning relatively small patches across the landscape. Because of the variable nature of vegetation at the landscape scale, some patches will probably burn frequently while others will burn infrequently. The resulting shifting mosaic will be mapped through time and the response by elements of the biota, especially selected threatened and fire regime specific taxa, will be monitored. Monitoring will also be carried out at sites from which fire is excluded and sites experiencing fire regimes in accordance with existing management plans.

As part of a process of local community consultation, the Walpole Wilderness Area Community Advisory Committee (WWACAC) has been briefed on the project and have had opportunity to discuss the project, including location of the study sites. WWACAC supported the project (meeting 29th August 2003) and suggested London block and adjoining areas (Surprise block) as the preferred location. A round table on prescribed burning convened by Dr Christine Sharp MLC for the South-West and held in Walpole 30th October 2003 supported the need for further research on how to achieve fine-grained mosaics. Having identified a suitable study site, the next step will be to identify, locate and carry out assessments of populations of threatened taxa and populations of fire regime specific taxa (plants and animals). Biodiversity monitoring sites will also be established in various primary landform units to monitor biodiversity more comprehensively. We will attempt to create a fine-grained mosaic using the frequent introduction of fire into the landscape (patch-burning). Monitoring sites will be installed and assessed over spring 2004 with trial burning commencing in summer/autumn 2005, although there may be a need to carry out some edge / protection burning in spring 2004.

The Fire Mosaic Project will establish long-term fire monitoring sites within the proposed Walpole Wilderness Area. There is ample scope for involving students, volunteers and community-based groups or individuals in this project and this will be pursued by the proponents. The project is intended to be landscape scale (several thousands of hectares) and the sampling methodology is aligned with that used for FORESTCHECK, which was developed out of extensive consultation with scientists external to the Department.

Biodiversity conservation is a key fire management objective and consistent with principles of adaptive management, fire management will be reviewed and if necessary, adjusted, in response to the monitoring results.

1. Introduction

Flammable vegetation and seasonal conditions of warm, dry weather have ensured that fire is a natural environmental factor, which together with climate, landform and soils, has operated over thousands of years to forge the remarkable biodiversity of south-west ecosystems. 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 (see Abbott and Burrows 2003).

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 to recover their populations. 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 frequent 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 extreme fire regimes - such as sustained high fire frequency or long periods of fire exclusion applied over large areas - can 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. Prior to European settlement, regular burning of parts of the landscape by Noongar people probably maintained a mosaic of vegetation at different stages of post-fire development (pyric stages) – from recently burnt patches to infrequently burnt patches, although there is mounting evidence that much of the landscape was maintained in an early post-fire state (Abbott 3003; Lamont *et al*. 2003). This fire mosaic probably contained the spread and intensity (severity) of wildfires. Very large and intense wildfires (so-called megafires) were not in the best interests of Aboriginal people or the environment generally, and were probably rare events.

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, property and industry. 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 ongoing research undertaken by a range of organizations over the last 40 years or so (see Abbott and Burrows (eds.)). Although our knowledge is incomplete, fire management must be underpinned by science and must be a process of continuous learning.

With respect to the ecological effects of fire, several themes consistently emerge from the contemporary global scientific literature (e.g. Whelan (1995), Bond and van Wilgen (1996), Trabaud and Prodon (eds.) (2002), Bradstock *et al*. (eds.) 2002, Abbott and Burrows (eds.) (2003)). Firstly, no one fire regime suits all organisms. For example, some elements of the biota benefit from frequent fire (e.g. grasses, annual herbs, some re-sprouters, large macropods, some fungi and some invertebrate groups), while others are disadvantaged (e.g. some late maturing obligate seeders, some mammals, some birds, some invertebrates). At the other end of the spectrum some elements benefit from longer intervals between fire and others are disadvantaged. A second emergent theme for conserving biodiversity at the landscape scale is that of spatial heterogeneity, or of a fine-grained fire-induced (fire-genic) habitat mosaic. A third theme to emerge is the need to protect ecosystems sensitive to fire from frequent fire or large intense fires. Examples include riverine, aquatic, peat substrates, some wetland and heathland complexes and granite outcrops. However, even these may require fire at some stage for their rejuvenation (perhaps with the exception of peat substrates).

A variety of fire regimes may be applied in south-west landscapes to achieve a variety of management objectives. These include fire regimes;

- to manage fuel levels based on fuel accumulation rates,
- to protect or promote specific threatened species or communities based on known life histories,
- for enhancing biodiversity generally, based on vital attributes of key fire response taxa,
- for scientific purposes, including fire exclusion, and
- to regenerate specific species, such as silvicultural burning in areas available for timber production.

In addition to the above, a landscape-scale proactive use of fire for biodiversity conservation that is worthy of investigation in an adaptive management framework is creating and maintaining fine grain fire-induced habitat mosaics.

1.1. Creating fire-induced mosaics in the landscape

The fire management challenge in many south-west landscapes is to devise and implement fire management strategies that are diverse, provide a fine-grained habitat mosaic, that protect fire regime specific elements, that enable the periodic regeneration of fire-promoted elements and habitats, that minimises the adverse impact of wildfires and that are practical and affordable.

There are a number of approaches to achieving these objectives and they include:

- Varying the fire regime applied to a fire management unit. This includes varying the season, frequency and interval of fire based on vital attributes and life histories of key taxa (fire regime specific taxa).
- Implementing mostly patchy burns with occasional near complete burn. That is, create patchiness within patches (an intra-patch mosaic).
- Small-grained fire-induced mosaics can be achieved several ways including (but not limited to):
    - Physically breaking the management unit up with a network of mineral earth or natural physical fire barriers and treating each cell differently. This is generally unacceptable and undesirable.
    - Introducing fire into the landscape when fuel moisture (flammability) differentials exist across the landscape particularly during late autumn, winter and spring. This comes with the risk of re-ignition and complete burnout as the season and vegetation dries with the onset of summer.
    - Using wind-driven strips in heath or mallee heath vegetation.
    - Using specific lighting/ignition patterns and time of ignition.
    - Introducing fire into the landscape frequently when fuel flammability (quantity and cover) differentials exist (similar to the likely Noongar Aboriginal burning regime). The resultant mosaic and effects on biodiversity at the landscape scale over time is poorly known but should be trailed and monitored. Note: The regular introduction of fire into a landscape does not equate to the “frequent burning” of the landscape, or of ecosystems therein. Under such a regime many elements will escape fire or will be protected from fire by adjacent natural low fuel areas or recently burnt patches (self regulating fire suppression).

2. Trial Objectives

2.1 To apply frequent and planned introduction of fire to the landscape (patch-burning) to create a fine-grained mosaic of interlocking patches of vegetation at different stages of post-fire development.

2.2 To monitor at both the patch scale and the landscape scale, the effects of the resultant mosaic on biodiversity; specifically:

- Abundance of fire regime specific plant taxa, DRF and reserve listed taxa (e.g., *Synaphaea* sp., *Lambertia rariflora* subsp. *lutea*, *Banksia quercifolia*, *B. occidentalis*, *Dryandra formosa*, *Hakea oliefolia*)

- Geophytes (Orchidaceae, Droseraceae especially)

- Abundance of fire regime specific fauna and condition of associated habitats (e.g., Honey Possum (*Tarsipes rostratus*), Quokka (*Setonix brachyurus*), Mardo (*Antechinus flavipes*), Sunset Frog (*Spicospina flammocaerulea*)).

- Reptile assemblages

- Bird assemblages

- Invertebrate assemblages

- Vascular plant assemblages

- Fungi and cryptogams.

Specific taxa and habitats to be studied will depend on the selection of the study site.

3. Methods

The techniques described above can be used to create a fine-grained mosaic over time. Each technique has advantages and disadvantages and each will result in a different mosaic. Low intensity prescribed burning at 5-10 year intervals during spring when moisture differentials exist has been routinely applied over many areas for several decades. However, there is the risk of re-ignition later, leading to burning out of the entire landscape and to possible fire escape. Such a strategy usually results in a relatively coarse-grained mosaic, resulting either from prescribed burning or from wildfires.

Alternative techniques, such as frequently introducing fire into the landscape in summer/autumn has not been trailed, evaluated and properly monitored over a large area (thousands of hectares) anywhere in the world to our knowledge. Throughout the south-west forest region (Jarrah Forest and Warren Bioregions), the rate of post-fire production of live and dead vegetation, which becomes the fuel for a bushfire, is such that it is not mature as a fuel until about 3-4 years after fire. Prior to this, fire spread, even under conditions of HIGH fire danger, is likely to be very patchy and restricted to relatively small areas with a dense overstorey canopy cover, or grassy understoreys. However, beyond about 3-4 years after fire, more of the landscape is flammable, and by about 5-8 years after fire, the vegetation/fuel complexes are sufficiently well developed so that virtually the entire landscape will support an intense bushfire under dry, windy conditions.

Fires burning in light and patchy (immature) fuels will not only be very patchy, but will be very low intensity. This combination of very patchy fires burning at very low intensity and only burning in the more flammable parts of the landscape provides opportunity for fire regime specific species and communities, that mostly occur in less flammable parts, to;

- escape the fire (not burn),

- be protected from fire by intervening low fuel patches,

- or survive very low intensity fire.

We hypothesise that over time, the frequent introduction of fire into the landscape every 2-3 years will result in a fine-grained mosaic of patches at different stages of post-fire development. The precise nature and scale of the mosaic is unknown. In addition, we hypothesise that the resultant mosaic will afford protection to fire regime specific species and communities (which will escape fire or will not be adversely affected by very low intensity fire) and will significantly break up the run and intensity of an impinging wildfire. It is reiterated that because of the patchy nature of vegetation/fuels, the frequent introduction of fire does not equate to frequent burning of the landscape. We hypothesise that a relatively small proportion (<20%) of the landscape will in fact carry fire, hence burn, regularly.

3.1 Location

Following a preliminary field inspection the trial will be located in London forest with reference sites in adjoining areas (Surprise forest). These areas are within the proposed Walpole Wilderness Area (WWA), Frankland District. Reference areas will be a) subjected to the standard fire management treatments prescribed in the various planning documents for the area and b) areas identified as 'no planned burn' areas.

3.1.1. Characteristic of London block that make it suitable for this trial:

- There is a range of vegetation types, which are representative of the Denbarker (or main part of WWA) area. For example, there are extensive sedgeland/heathland (flats) systems (Caldyanup) with a good representation of the various floristic and structural types that are present throughout the area. Other vegetation types include jarrah/sheoak woodland, jarrah/marri woodland, jarrah/marri forest, stands of bullich, red flowering gum and blackbutt, peat communities (a range of types), banksia woodlands and karri/tingle forest.
- Quokka (*Setonix brachyurus*), an example of a mammal that has specific habitat requirements, are present.
- *Lambertia rariflora* subsp *lutea,* a priority listed species that is fire regime specific, is present with a mix of age classes. There are also populations close to existing roads that could be excluded if necessary. *Banksia quercifolia*, a fire regime specific obligate seeder with canopy-stored seed is also occurs in the area.
- There are priority listed fire ephemerals present, such as *Mitreola minima* (Priority 2).
- Three (possibly four) known Sunset Frog populations present, with a good history of monitoring.
- Provides an opportunity to examine how mosaics might develop within the extensive wetlands (flats) systems and how the flora and fauna respond.
- There is a range of fuel ages surrounding London forest, which provides an opportunity to create a low fuel zone surrounding London to protect the study site.
- Significant granite outcrop present - although it does not contain any of the granite specific priority or DRF species such as the Lindesay endemics or *Gastrolobium spp.*, *Astartea* spp. or *Chamelaucium spp*.
- Has all-weather access to all boundaries.

3.1.2 Uncertainties and risks associated with this trial

- Inability to establish a fine-grained mosaic by frequent patch-burning.
- Albeit remote, there is a possibility of the loss of a priority listed flora population/s. It is possible to collect seed and/or exclude populations from fire.
- The denser vegetation type is linked to the southern boundary of London block, which could result in an increased risk of fire escape, particularly as burning may be carried out in summer/autumn prohibited period.
- Larger area with greater range of vegetation types, so could be operationally more difficult to contain fire within the boundary; i.e. greater risk of re-ignition and fire escape.

- Adjacent to reintroduction site for Tammar and Woylie (animals were released approx 1.5 - 2km south of Boronia Rd), which may also create issues with burning Soho (i.e. need to leave some refuge areas).
- Ongoing commitment of resources to continue the project to meet objectives.
- Lack of community/organizational support for the trial.
- Wildfire
- Adverse weather conditions impacting on ability to carry out burns

3.2 Fire frequency, prescription and lighting patterns

Fire will be introduced into the landscape under moderate / mild conditions in summer, spring or autumn and at 2-3 year intervals. At each stage of fire introduction, the intention will be burn smaller patches across the landscape (<500 ha), with each fire introduction burning <20% of the landscape. The lighting pattern(s) are to be decided and will be modified as we learn more. However, a starting point may be to set widely spaced spots (e.g. 300m x 150 m spacing) during summer, early autumn put in around the peak of the day but on a falling hazard. This will be carefully monitored to see how many and which of the ignition points develop/sustain and which extinguish and the subsequent fire behaviour – area burned over the ensuing days. Analysis following the first year’s ignition will provide better information to guide future lighting patterns to achieve the long-term objectives. Subsequent lightings will aim to avoid those burnt previously, the aim being to create a fine-grain mosaic of burnt patches at different seral (post-fire ages) stages.

Burning in the prohibited season, or burning under conditions that exceed a fire danger rating of HIGH, will require a suspension to the Act from FESA/local bushfire authority.

Table 1: Proposed patch-burn prescription (may be adjusted through life of project)

SDI	Jarrah SMC	Tower wind speed	Jarrah ROSI	FFDR	Temp.	RH	Lighting pattern
>1000 (dry soil)	6-14%	10-25 kph	40-100	MODERATE to HIGH	23-32	35-60	300m x 150m initially

A District Project Officer, including someone responsible for the planning and implementation of the burning, will need to be identified.

3.3. Sampling methodology

Intrinsic and unique elements of this project, fundamental to its objectives, are that it is landscape-scale (total study area ~7,700 ha) and monitoring will be medium to long term. The design will be based around the BACI experimental design (Before, After, Impact, Control) with replications through space and time. Sampling will be stratified according to three landscape scale “fire treatments”:

a) Fine-grained fire mosaic

b) Routine fire management as guided by the area management plan and,

c) No planned fire

Monitoring will concentrate on DRF, priority listed taxa, flora (obligate seeders, canopy stored seed, long juvenile period) and threatened and fire regime specific fauna. Populations of these taxa will be identified and sampled using permanent grids. The number and size of the sampling grids will vary according to individual species needs. This will be determined following field inspections and an initial assessment of variability. The intention will be to carry out sufficient sampling to detect any change in population abundance (mortality and recruitment) as a result of the fire treatment. FORESTCHECK type monitoring grids will be installed to monitor biodiversity more comprehensively.

Within each landscape scale fire treatment, sampling will be stratified according to the 3 dominant landform systems (Caldyanup, Collis and Lindesay). Final classification will depend on study site selection, existing mapped units, study of aerial photographs and field inspections. In all, 18 comprehensive monitoring grids will be established. It would be preferable to increase the sampling intensity, but resource and time limitations will probably preclude this. Sample intensity will be reviewed after the first round of sampling and assessment of variation and statistical power. In addition, taxon specific sample sites will be located where DRF, reserve listed, threatened fauna or fire regime specific taxa occur.

The sampling protocols to achieve the objectives above will essentially follow those developed for the FORESTCHECK monitoring program (see below). In this trial, all grids described below will be sampled at 3 year intervals initially then reviewed.

3.4 Mapping the Mosaic

Recently developed satellite imagery technology (CALM Fire Management Services) will be used to map the fire-induced mosaic. Imagery will be analysed and maps prepared after each introduction of fire into the study area. Areas that did not burn, areas that burnt and fire severity will be mapped. A chronological sequence of such maps will result in a map of the scale and nature of the mosaic (fire history for various ecosystem elements or habitat types represented in the landscape). Identification and mapping of ecosystem elements or habitat types will occur on final selection of the trial site. A map of the existing mosaic on the study site will need to be prepared from historical imagery captured after the most recent fires. Mapping may require some ground-truthing.

Broad vegetation assemblages/habitat types will be identified and mapped using existing data (e.g., Mattiske & Havel vegetation assemblages), aerial photographs and local knowledge. Known locations of DRF, reserve listed species, threatened fauna, fire regime specific taxa and communities will also be accurately mapped so that these can be carefully monitored. A fauna and flora species list will be prepared for the study area (source: WA Museum, WA Herbarium, local knowledge). Fire history (since 1950s?) is being prepared for the proposed Walpole Wilderness Area.

3.5 General Biodiversity monitoring sites

As discussed above, in addition to close monitoring of DRF, rare and endangered, priority listed and fire regime specific taxa etc., comprehensive FORESTCHECK biodiversity monitoring sites will be installed, as follows.

3.5.1. Monitoring Birds

Leader
Graeme Liddelow

Members
Chris Vellios, District & Region Staff.

Objectives
To count and record all birds that land in or utilize the 100 m x 100 m (1 ha) grid with no distinction between sight or sound recording. Birds flying over or through the grid will be noted as a species record only.

Reporting will be by species richness and total abundance per grid as well as trends of species richness and abundance.

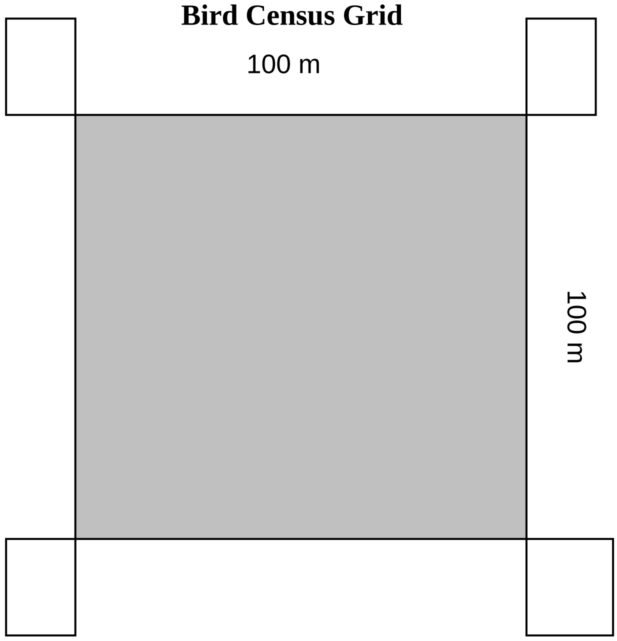
Past experience indicates that there will be too few records to analyse the data in any great detail.

Methods
There will be two bird census grids in each of the major vegetation types in the reference areas and the treatment area. Each site will be censused five times during spring using the area search method in the central 1 ha core grid. Each census will be carried out at least 7 days apart. Censuses will commence at sunrise and continue until 3 hrs after sunrise in fine still weather. Each team member will census one site (i.e. four grids) on any one day and members will rotate through the areas over the five counting days.

Individual censuses take 20 mins for the 100 m x 100 m grid and the team member will spend that time walking around the grid recording on the field sheet (attached) all the birds detected by sight or sound.

Data Analysis
Total abundance, species richness, individual species trends and comparisons between treatments i.e. external reference area, coupe buffer, shelterwood and gap with time since treatment.

Bird Census Grid



3.5.2 Monitoring mammals, reptiles and amphibians

Leader
Graeme Liddelow

Members
Bruce Ward, District & Regional staff

Objectives
To trap and record the suite of medium- and small-sized mammals, reptiles and amphibians within the FIRECHECK grid.

Mammals will be individually marked and records of their species, sex, weight and breeding status noted. Reptiles and amphibians will be recorded by species only.

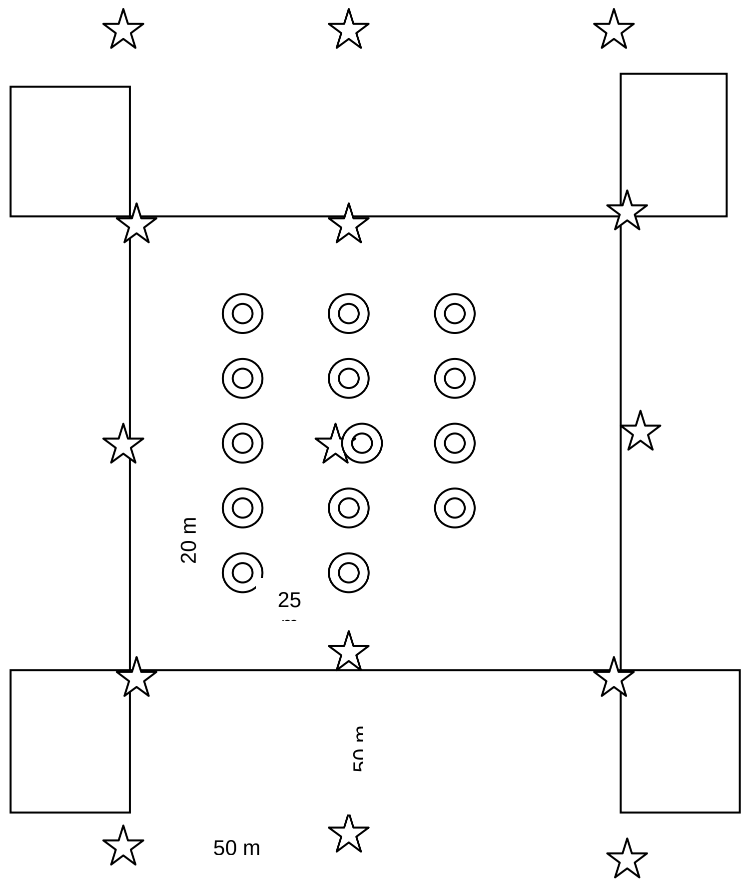
Methods
Pitfall traps, (20 L buckets; 25cm wide x 40 cm deep) with a 5 m long flywire fence, will be established. Wire cage traps (20 cm x 20 cm x 45 cm).

There will be two small vertebrate grids placed in each major vegetation type in the treatment area and the reference areas. Traps will be set on the Monday (see plot layout attached) and then run for the next four mornings i.e. Tuesday, Wednesday and Thursday and Friday, after which the traps will be closed (pits) and or removed (wire cages). All animals caught will be processed on the site of capture, and then released immediately. Species, sex, weight, point of capture, breeding status and individual marking will be recorded for all mammals and only species and point of capture recorded for reptiles and amphibians (see field sheet attached).

The trapping will be with pit traps for small mammals, reptiles and amphibians and also wire cage traps for the medium sized mammals. Both spring/summer and autumn trapping sessions will also include checking of nest boxes for the presence of phascogale/mardo. Each day of trapping will also require the 20 1m x 1m x 7 cm deep sand pads spaced 500 m apart along a track to be checked for fox and cat abundance. A scent lure is buried in the centre of each pad, and the pad is brushed clean each day. Sand pads will also record Chuditch and other fauna tracks.

Data Analysis
Species richness, abundance, sex ratios, trap percentages, and comparisons between treatments within the site and with other areas. Feral animal abundance will be measured.

TRAPPING GRID LAYOUT



3.5.3 Monitoring invertebrates

Leader
Janet Farr

Members
Allan Wills, Tom Burbidge and District and Regional staff

Objectives
Invertebrate monitoring is intended to provide a method to easily capture data describing the abundance and community composition of readily visible and highly identifiable components of the invertebrate fauna. The data are intended to provide a means for long-term monitoring of the state of recovery of invertebrate fauna due to disturbances such as fire and natural variation. In addition, Gondwanan relic invertebrates will be noted in all habitats when observed (see appendix for summary of Gondwanan taxa).

Design
The design is potentially factorial with:

2 sites of different treatment (reference area, treatment area),
3-4 major vegetation types,
2 sampling seasons (autumn and spring).

In its simplest interpretation, the design is based around a cluster of treatments at each site such that a site = statistical "block" = replicate. This will provide the greatest flexibility in development of analytical designs as data accumulate.

Sampling for invertebrates will be within a 1 ha quadrat within each treatment at a site. Quadrats will be placed to maximize distance from treatment edges.

Sampling methods
Five types of sampling method will be undertaken:

1. Light trapping for night flying Gondwanan orders.
2. Foliage beating and sweep netting for day active Gondwanan orders.
3. Canopy observations of known pest species.
4. Area searches of ground habitats.
5. Pitfall trapping.

Because sample recoveries from all methods are likely to be affected by temperature and rainfall conditions, air and soil temperatures and rainfall events will be recorded as additional covariates during field sampling. Measurement of sampling conditions covariates and diversity and abundance covariates will free the design from a need to sample all vegetation types and treatments at the same time and in the same conditions.

Light trapping
One trap per grid site to be placed in a clear area within the site so as to maximize light field attraction within the plot. The preferable killing mechanism is pest strips (placed in the capture bucket) to maximize quality of specimens. Traps will be open at a site for 1 night allowing 4 treatments at all 3 sites to be sampled in one week with daily clearance. This will be repeated 3 times within each trapping season (3 wks), such that there will effectively be 3 trap nights per quadrat for each sampling season. Lights will be functional from sunset to sunrise. Capture will be placed in a paper bag for each site and clearly labelled with site details and date. Should storage over 2 days be required, the paper bag containing specimens will be placed in a plastic bag and the sample frozen. Trapping periods are preferably close to a new moon to avoid light interference from a full moon.

Foliage beating and net sweeping
Within each quadrat (1 ha) sampling will be twice daily (am and pm). Understorey canopy beating will be conducted for 1 hr. Net sweeping (including targeted pursuit) will also be conducted over 1hr. Sampling times will be broken into ½ hourly segments and each sampling technique alternated (e.g. ½ hour beating, ½ hour sweeping, ½ hour beating, ½ hour sweeping) for each sampling period. Bulk samples from each ½ hour will be sealed in a killing bag containing a (pyrethroid?) infused swab. Alternation of sampling methods and morning and afternoon sessions will reduce diurnal bias and increase operator efficiency. Should captures over the first sampling season show no difference between am and pm samples or pm is the more effective period, then the morning sampling session will be cancelled.

Observations of known pest species
Three known pest species will be monitored.

1. Jarrah Leaf Miner (JLM), a Gondwanan relic species. The jarrah canopy will be visually scanned for 10 min using binoculars. Evidence of JLM presence (e.g. shot holes in leaves) will be recorded as 0 = absent, 1 = present, 2 = abundant. Abundant JLM will be classed as greater than or equal to 5 shot holes per leaf present.
2. Gum Leaf Skeletonizer (GLS). Both the upper Jarrah canopy and understorey will be visually scanned (10 min) for (a) leaf damage peculiar to GLS, (b) GLS egg rafts, (c) GLS moulting casts, (d) GLS larvae. Each individual symptom will be scored as present or absent. In addition a general score for abundance level will be given as 0 = absent, 1 = present, 2 = abundant (greater or equal to 5 symptom groups found)
3. Bullseye Borer. Tree boles will be scanned for borer symptoms (10 min) (e.g. kino dribble stains, bulls eyes, helical scribing in bark). Recording will be 0 = absent, 1 = present, 2 = abundant. Abundant will be classed as greater than 4 symptoms per tree.

Area searches within microhabitats
Within each quadrat, sampling by area searches will be stratified according to six microhabitat types.

1. Leaf litter. Within litter beds.
2. Bare ground. Areas of ground without litter covering that are not ash beds.
3. Lower boles. Underbark shelters and accessible hollows in lower boles below a height of 50cm.
4. On/in/under coarse woody debris. Count logs and large branches but sample from all sizes of debris.
5. Moss swards. These develop on ash beds and logs.
6. Ashbeds. Areas of ground upon which large pieces of coarse woody debris fallen logs and branches) have burnt completely or almost completely to ash.

Search at least 3 separate areas of each microhabitat type in order to disperse sampling effort. If fewer than 3 separate areas of a type of microhabitat are present, then it will be treated as absent or insufficiently represented within the quadrat.

Search each microhabitat type for 15 minutes collecting voucher samples and recording abundance details of fauna. Each voucher specimen(s) to be given a unique identifier and stored separately in 70% ETOH at time of collection to minimize subsequent sorting. Sample within two time intervals 0900-1100 and 1500-1700.

Pitfall trapping
Pitfall sampling will not be habitat stratified. Place 10 traps at 10m intervals along a quadrat diagonal. Open pitfall traps at about 1215 PM and close 24 hours later. Trap cup size 90mm diameter by 110 mm deep. Use Galt's solution as a trap preservative only. Combine the contents of all 10 traps. Strain bulk sample through 0.2mm sieve and transfer to 70% ETOH for permanent storage in sealable glass containers enclosing sample details. Sample details to be written in B or 2B pencil on durable card.

Operator effort
Sampling is to be carried out by a three-person team. This will enable more or less simultaneous operation of all sampling methods within a site.

Light trapping
All persons assist with installation and portage. One person to manage samples.

Beating sweeping
One person to complete beating/sweeping. All assist with samples.

Area searches
One person will collect specimens and call observations. Another person will tote equipment and specimen containers, write observations, manage specimens, crosscheck with reference specimens, timekeep. This avoids the step of later recombining two sample streams. Daily data collection will be carried out in two periods of intense collection interspersed with less intense activities such as management of pitfall traps, site description and photography. Adequate intervals for meals, refreshment, planning and sample management are allowed that can also act as time buffers to prevent the concertina of intense data collection intervals due to unforeseen difficulties.

Variables (recorded on a durable A4 datasheet)
Site details
Site #
Date
Latitude GPS
Longitude GPS
Sketch map of landmarks and photopoints within and around quadrat
Silvicultural treatment
Principal vegetation

Sampling conditions
Frequency of microhabitats Habitat 1…H6.
Air temperature @ Time 1, T2, T3, T4.
Soil temperature @ Time 1…T4.
Rain events
Cloud conditions

Light trapping, Beating/sweeping, Area searches
Specimen # (S1…Sn)
Microhabitat source (H1…H6; BS1 = beating, BS2 = sweeping, L = light trapping)
Abundance (Coded: 0 = not found; 1 = few found (1 - 10); 2 = commonly found (>10)
Description of readily visible identifying features (colour, size, shape, ornament, nest type etc).

Pitfall samples
Bulk contents of 10 pitfalls for later sorting. Coded on data sheet as P = Pitfall.

Sampling schedule
Sampling of a single site with four major vegetation types is expected to occupy about a week. Allowance is made for travel to and from a distant site and completion of the sampling cycle within a 5-day working week.

Treatments will be sampled in a blocking pattern from remove fatigue and experience biases.

Data Analysis
Presence/ absence data will allow ordination of sites and detection of changes in community composition over extended periods by trend analysis. Initial data analysis will focus on identification of useful indicator species of ecosystem processes.

3.5.4 Monitoring vascular plants, cryptogams and soils

Plants

Leader
Bruce Ward

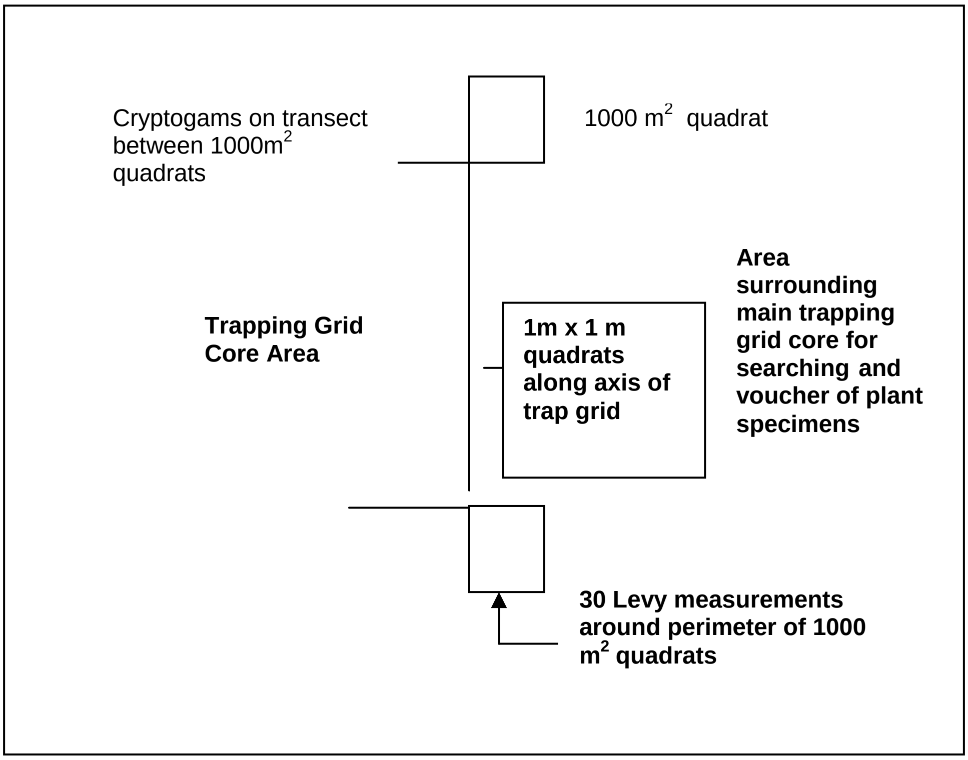
Members
Ray Cranfield (Botanist), District and Regional staff

Objectives
1. To monitor the impacts of frequent mosaic burning on plant species richness, species assemblages, abundance, cover and structure.
2. To monitor changes in population density (mortality vs recruitment) of selected threatened and fire regime specific taxa.

Methods
1. For each treatment, three grids will be established in each of the 3-4 broad vegetation types (frequent fire and reference area). Each grid will consist of

- Four quadrats each 1000 m^2 (31.6 m x 31.6 m), permanently marked with a dropper at each corner. The quadrats will be located at the corners of each mammal trapping grid. Records of all species and their life form will be collected.
- 1 x square metre quadrats will be established along the side of the mammal grids and marked with droppers at 10 m intervals and 2 x 1 m^2 quadrats offset 5 m either side of the peg. Records of all plant species and counts of individuals including Jarrah/Marri seedlings.
- Around the perimeter of the 1000 m^2 quadrats point transects using Levy rods will measure vegetation height and cover. Heights will be assessed using the drop plate method and recordings of height of contact by height class, number of contacts in each class whether live or dead and species making contact.
- To complete a total listing of species for the site the area around the mammal trap grid will be searched for any additional species not recorded in the 30 m x 30 m quadrats.
- Vouchering of all species will be conducted from the surrounds of the mammal grids and outside of any vegetation quadrats. A combined voucher set will be constructed for one sampling site (containing 4 treatments). Provided the treatments are within close proximity (within 1 km), if the range between treatments is considered to be too far (>1 km) and the risk of different vegetation associations occurring, then a separate voucher set will be constructed for that grid.
- Map occurrence of *Phytophthora cinnamomi*, evidenced by death of indicator species and collate the information gathered by dieback interpreters.

Plot Layout



Threatened taxa and fire regime-specific taxa

As previously discussed, individual sampling quadrats will be established within populations of the above. The size and number of quadrats will be determined after field inspection of sites. Numbers and height of individuals will be recorded to monitor the density (numbers) of the population. Other life history observations will be made including juvenile period, seed production, post-fire regeneration strategy, seedling density, mortality, longevity etc.

Data analysis
- Species richness per 1000 m^2 by treatment with time. Provide species list and tabulated number of species by life form guild and fire response mechanism.
- Mean species richness per square metre by treatment over time. Tabulated mean number of species with standard error.
- Mean plant density per square metre by treatment over time. Calculate mean plants per square metre by treatment and graph trends over time.
- Mean cover and height changes over time for each treatment. Tabulate mean cover and height for each treatment with standard error.
- Vouchered specimens lodged with the WA Herbarium – include fertile or sterile plant material.
- Analysis of various guilds or fire response categories.

Other
Classify plants by life form guilds:
Tree, woody shrub, perennial herb, geophyte, short-lived herb (regenerates by seed), grass (perennial), sedge, fern and whether native or weed.

Classify by fire response categories: A. Seeders (Seed stored in soil, seed stored on plant (serotinous), no seed on site (e.g. blows in). B. Resprouters: (epicormics, woody rootstocks, fleshy below ground organs).

Cryptogams

Leader
Ray Cranfield

Objectives
To record, compare and monitor taxon diversity within various treatments and vegetation types types, in particular

- Species richness and abundance
- Habitat and substrate abundance
- Substrate usage
- Disturbance effects

Equipment Requirements

- Digital camera (Site data and species images)
- 10 x 10 cm clear plastic grid
- 100 m tape
- Collection book (species)
- Data sheets
- Site maps

Methods
Field
Each site will be assessed every 3-5 years over the winter months into spring. (June-November) after the initial survey. This will involve the following tasks:

1. Overall site classification to be assessed and recorded.
2. Microhabitat requirements assessed and recorded.
3. Permanent marker positioned.
4. Species collection of whole site area carried out, within in 300 m x 300 m quadrant but outside 100 m x 100 m inner quadrants.
5. 2 x 100 m lines established (bearing).
6. Four 10 cm x 10 cm species diversity and occurrence quadrats carried out at every 10 m.
7. Indicator species (from grids) vouchered and identified.
8. Site species uniquely number identified.
9. Data on each species scored on site.

Laboratory
Each species placed into a separate paper bag and air/oven dried.
Each species identified as far as possible or sent to experts.

Other

- Voucher preparation and databasing of samples for lodgement into state collection.
- Each sample mounted in sample box ready to incorporate at Perth Herbarium.
- Samples sent to Perth Herbarium.
- Data sheets and collecting book production

Data analysis

- Cryptogam species listing for each site.
- Species richness.
- Cryptogam density.
- Habitat requirements.

- Substrate usage.
- Facultative host/s.
- Effects of treatments upon species occurrences.

3.5.5. Monitoring macrofungi and coarse woody debris

Leader
Dr Richard Robinson

Members
Bob Smith (and District and Regional staff??)

Following consultation with Dr Robinson, it is clear that given the narrow seasonal opportunity for assessing fungi, and his current work commitments, he is unable to participate in this project at this stage. Alternatively, Dr Robinson has suggested that he could carry out a retrospective survey in 3-5 years by targeting monitoring sites with different fire histories within the mosaic. The basic protocol that is used in FORESTCHECK, and which could be applied to project "FIRE MOSAIC" is as follows:

Fungi occur on trees, dead wood and on the ground and have specific microclimate requirements. Transects are the most appropriate sampling method and will take in the wide variation of substrate and microclimate present in a forest.

The only practical method of monitoring forest fungi is by measuring fruitbodies. This presents several problems:

(i) fungal fruiting is weather dependent, and with a low monitoring frequency temporal variation in the species recorded can occur.

(ii) the presence of fruitbodies of a particular species of fungi indicates the presence of the fungus, however, the absence of fruitbodies does not indicate absence of the fungus (it may be present in the soil/wood substrate but has not fruited).

It is not meaningful to measure abundances (numbers) of fruitbodies of a particular species, as one mycelium in a substrate may produce either multiple or single fruitbodies and abundance will vary from year to year. A better measure is the presence or absence of fruitbodies of a particular species.

Fungi play three major and very important roles in forests, acting as (i) nutrient suppliers to plants (in the form of mycorrhizas), (ii) nutrient recyclers (decomposers) and (iii) pathogens.

Objectives

1. To monitor and record the species of macrofungi fruiting in the various fire treatments. Trends in species richness and abundance will be analysed over time.
2. To measure and record the amount of coarse woody debris (CWD) on the ground in the various fire treatments. Trends, within and between the various treatments, will be analysed over time.

Methods
At each site, grids are to be installed in each of the 3-4 major vegetation types in both the treatment and reference areas. Grids are 9 ha (300 m x 300 m) and will contain plots, transects etc for all monitoring groups. Sites to be assessed every 3-5 years in the autumn (mid-May to late-June, depending on rainfall and temperature). The following protocol is to be followed at each grid.

Macrofungi
Site preparation:
At each grid, establish and permanently mark 2 x 200 m transects. The origin of each transect will be 50 m in from the origin of the centre line and perpendicular at 90 m on each side of the

centre line (see grid design attached). The origin of each transect will be permanently marked with a dropper and its GPS recorded. The bearing of each transect from its origin will also be recorded and droppers put in at 100 and 200 m. The width of each transect will be one metre, the actual line of the transect being the "inside" boundary of the assessment area.

Data collection
Along each transect, the distance from the origin, the species and the number of fruitbodies, and the substrate will be recorded. Additional comments to be noted where necessary. See data sheet (attached). Each grid will be visited three times on a fortnightly basis in autumn. Voucher collections to be made of each species collected in each vegetation type.

Litter and Coarse Woody Debris
Site preparation
One hundred metres of each macrofungi (MF) transect will also be used to assess CWD. One CWD transect will cover the first 100 m of a MF transect and the second CWD transect will utilize the second 100 m of the other CWD transect. Litter will be collected from 22 x 0.05 m^2 quadrats placed every 10 m externally adjacent the CWD transects.

Data collection
For each transect, a 100 m tape will be laid out. The diameter of each piece of CWD, larger than 2.5 cm in diameter, that the tape passes directly over will be recorded. At least 50 data records will be needed for each grid. If 50 records are not gained an additional transect will be surveyed and used. Additional transects will be marked with droppers, and GPS of origin, bearing and length will be recorded. Each grid will be assessed in autumn. Litter from each quadrat will be collected in paper bags numbered 1-22, number 1 being at the origin and number 11 at the end of the first transect, number 12 being at the 100 m mark and number 22 at the end of the second transect. Site details will be entered onto a master map for each grid.

Data analysis and storage
Each year species richness and abundance will be calculated for each treatment at each site. Species richness and abundance will be compared between treatments at each site, between sites and between forest types. Over time species richness and abundance curves will be determined for each treatment in each forest type.

Macrofungi will also be assigned to life-mode type (e.g. saprophytic on wood, saprophytic on leaf litter, saprophytic on twigs, fungi fruiting on soil). Use of ranking's, such as 0 (not found); 1 (few found); 2 (commonly found), will be explored.

Another method of monitoring change is to measure the change in ratio of Mycorrhizal, Saprotrophic and Pathogenic fungi. Knowledge on certain species of fungi in all these groups is available. Monitoring the presence and absence of these species over a long time frame will indicate what ratio of M:S:P is present on the monitoring sites. Although the M:S:P: ratio cannot be interpreted as yet, in time it may be possible to determine which M:S:P ratio is indicative of a healthy forest (control), and how or if management treatments affect this ratio.

The volume (m^3 ha^{-1}) of CWD will be calculated using the formula and method of Van Wagner (1986). Litter samples will be oven-dried for 24 hrs and dry weights used to determine litter loads (tonnes ha^{-1}). Litter loads and CWD can be compared between treatments at each site, between sites and between forest types. Litter and CWD accumulation curves will be generated as data accrue.

Data will be entered onto Microsoft EXCELL worksheets. Originals to be stored at the Manjimup Research Centre, on the Group leader's PC and backed up on the local server and a floppy disc/CD. New data for each year will also be sent to the FIRECHECK Data Co-ordinator (Amanda Mellican) at the Kensington Research Centre.

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