Fire regimes in Australia's rangelands: a lack of information

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Abstract

The are two aspects of fire in the rangelands which can be addressed. The first deals with fire regimes. Fire regimes are perceived as an important factor to survival and / or persistence of many species, both plants and animals. Unfortunately fire regimes are a complex measure; a function of fire frequency, intensity, season, type, patchiness, etc. Despite this accepted definition, it is still a very difficult factor to define or quantify on a spatial scale. For the vast majority of Australia's rangelands, there is an inadequate record of fires and therefore it is difficult to calculate or describe current fire regimes and impossible to determine the change from past times. In some areas fire has been removed from the landscape and the potential to use and understand its value as an ecological driver are very limited.

The second aspect deals with the direct effects of fire on individual plants and animals. Studies within and beyond the rangelands have contributed information to this area, primarily from observations associated with a single fire event. However, for the majority of species the direct effect of a single fire remains uncertain. The direct effect of multiple fires and varying fire regimes is even less certain. It is based primarily on observations rather than measurements but this provides the basis for implementing fire management programs within an adaptive management framework.

Introduction

This draft report is based on the series of points identified in the proposed outline submitted to the workshop organizers. Each point of the outline is provided in bold as a dot point with an expanded description. The report by Whitehead *et al.* (2001), that was based on a previous rangeland biodiversity monitoring workshop, provided a good information base on fire regimes and the appropriate sections are recommended reading and included as Appendix 4 for readers with access to the full report.

- **Brief summary of information associated with fire in rangelands. Stratification on the basis of land use; pastoral, aboriginal, conservation.**

The intent was to provide a background, but unfortunately there has been insufficient time to date; caused by too many fires in central Australia. This section could expand on the overview within the Whitehead *et al.* (2001) report with specific information on the variations in the use of fire and attitudes toward fire between land tenure classes. There are also differences between states and most significantly across the range of climatic regions from the arid to the tropical savannas.

- **Comments on the progression of land management changes in the rangelands which has affected fire regimes (i.e. spread of pastoralism, shifts in aboriginal populations), and the resulting regional differences of the past and current fire regimes.**

This could be a component of the previous section providing a historical perspective on changes that have influenced fire regimes on a regional basis. A general overview of these issues was provided by Woinarski (2001a) in sections 5.0, Threatening Processes and 5.1, Changed fire regimes (provided in Appendix 4 of this report).

There is a need for further descriptions to be made on a regional basis, with input from local experience because the rate of change from the pre-european fire regime to the current state has varied. The rate of change was affected by the historical spread of pastoralism and other settlement patterns and the subsequent impact on the populations and lifestyles of the Aboriginal populations. Recording this information on a regional basis will reduce the use of widespread generalisation with regard to Aboriginal fire management activities that are not relevant in many regions. In addition, there are still significant changes occurring associated with the continued change of land management, land ownership and populations mobility and population density. Understanding these changes will help address future management issues. As an example the ability of the pastoral community to respond to the fire events in central Australia during the mid1970s has been significantly different from the similar fire events of the last 3 years. During the 1970s it was possible to mobilise hundreds of individuals to the fire ground. This included the station manager's family, the ringers, the stockcamp, plus many Aboriginal workers and their families. Over the past 25 years the rural population has decreased substantially. At the present time, a single family with only a handful of workers and a few contractors run most stations. The ability to mobilise a suppression crew has been very restricted and many fires could not be contained and the resulting impact on the pastoral enterprise was significant.

- **Review of available fire history databases within the defined area of the Australia's rangelands, including a description and custodial information. Identify areas were fire regime information exists.**

Numerous individuals from a variety of state agencies were contacted to provide a description of available fire history datasets. The result confirmed that knowledge of the fire history of the rangelands is incomplete and there are few complete databases. In general data exist at a range of spatial and temporal scales, but the greatest majority of the rangelands have no mapped fire history. Although fire exclusion is a dominant paradigm in many of rangeland areas the absence of a mapped fire does not necessary reflect the absence of fire.

A summary of the fire history databases within the 5 state areas of the rangelands is provided in Appendix 1. A map of the areal and temporal extents of the fire history databases will be compiled for display at the workshop. Although individuals representing most state government agencies indicated that work was in progress, it is seems unlikely that a comprehensive database will be compiled. The result indicates that the potential to progress the use of fire regimes information as part of biodiversity monitoring programs is very restricted. The greatest potential lies within the tropical savannas regions due to the high frequency of fire and the availability of numerous datasets. Within the semi-arid and arid rangelands areas, the southern portion of the NT has the most comprehensive database to help test the utility of fire regime information in a

biodiversity context. The recent period of extensive fires throughout central Australia has provided many new opportunities to work with updated fire information, but unfortunately the opportunity comes with some significant ecological impacts. Several hot fires are known to have burnt areas perceived as important long-unburnt areas, including the 80-year unburnt *Acacia ammobia* community in the southeast corner of Uluru NP and a suite of fire-sensitive plants in the Krichauff Ranges west of Finke Gorge NP. The ability of management programs to ensure these areas can recover is very uncertain. Fortunately at Uluru NP fauna and vegetation surveys over the past 15 years have provided a baseline of information, that can be used to monitor recovery and changes through time. However many areas in central Australia have little pre-fire information.

- **Review of "fire regime" metrics and the opportunity to calculate comparable measures from the available databases, including a description of issues associated with variable nature of individual fires.**

There is a variety of standard fire regime metrics that can be calculated from fire history data. The adequacy of the metrics is associated with the length of the fire history database and the variability of fire within the area of interest. Unfortunately the limited availability of fire history datasets restricts the opportunity to calculate many of these metrics.

The fire regime measures calculated for the 600,000 km² area of central Australia (Allan and Southgate 2002) included:

- Number of times burnt
- Minimum interval between fires
- Mean patch size
- Largest patch burnt
- Number of patches / 100km²
- Average proportion of region burnt per year
- Apparent fire return period
- Mean proportion burnt per year vs. variance of the proportion burnt per year.

An important study of fire regimes in relation to plant communities was undertaken in Guy Fawkes River National Park in northern NSW, beyond the rangeland area. It compiled a fire history using Landsat images and air photos for a 25 year period (Kitchin 2001). The fire history was used to calculate the following three fire regime metrics:

- NOF : number of fires
  Low (0) / Moderate (2-4) / High (>= 6)
- SIFI : shortest inter-fire interval
  Short (1-2) / Long (10-25) / Very long (>25)
- TSLF : time since last fire
  Short (<5) / Long (10-25) / Very Long (>25)

The three parameters were subjectively subdivided into the above categories and combined to create a final descriptive category.

- Final Category : LLL / MSS / MSL / MLS / MLL / HSS

The final categories were then used in the ordination and analysis of site data of plant species to determine plant species sensitivities to a variety of environmental factors including

physiography, elevation, geology (parent material), mean annual rainfall, mean annual temperature and incoming solar radiation.

Several studies have analyzed fire history data in the tropical savannas (Edwards *et al.* 2001, Russell-Smith *et al.* 1998). Only a few simple fire regimes metrics were used in their analysis of vegetation characteristics including sensitivity to fire. These were fire frequency, time since last fire and minimum fire interval, calculated on an annual basis. In addition the variability of area burnt was assessed over a 10 year period as early dry season fires versus late dry season fires for different vegetation and landscape units.

Vigilante (2002) modified the fire interval measure and calculated total fire-free months (TFFM) for fire history data in the tropical savannas of the Kimberley region of WA. TFFM was a measure of time between fires, although the annual fire history data was separated into periods of 4 months, representing the early dry season, late dry season and wet season. Therefore, TFFM was by intervals of 1/3 of a year not by individual months as the name implies. Nonetheless it was a refinement of fire history analysis in the fire frequent areas in the tropical savannas.

Price et al. (submitted) calculated 3 patch-based heterogeneity indices for a 20 years fire history dataset in the tropical savannas of Kakadu NP. Two of the indices were derived from measures of fire spatial patchiness calculated for each year separately and averaged for given time periods, and the third index was calculated for all years of data or for given time periods. Calculation of all three were based on a 5 x 5 cell array.

Measures of spatial patchiness
FPI-1 – based on a count of burnt cells surrounding the central cell, where 0 and 25 cells = 0 (no patchiness) and 12 or 13 burnt cells = 100 (maximum patchiness)

FPI-2 – the central cell was attributed as the count of unique orthogonal regions of bunrt/unburnt pixels, standardised to 100, where a value of 1 was reattributed as 0 (no patchiness) and 25 separate regions = 100 (maximum patchiness).

Measure of fire regime heterogeneity
FRVI-1 – the central cell was attributed as the sum of our separate values calculated for each 5 x 5 array of coefficients of variation derived for the following fire regime variables: (1) fire-free interval – largest interval (in years) between fires for each pixel; (2) total fire – total frequency of fire occurrence for each pixel; (3) time since last fire – time (in years) since a pixel was last burnt; and (4) late fire – total fire frequency of LDS fires. Separate calculations of FRVI-1 were undertaken for the period 1980-2000 and for each of the four 5-year periods.

Additional spatial datasets calculated at Kakadu NP included: terrain roughness; distance to drainage; distance to roads; human use intensity; management zones, and landscape units.

Price et al. (submitted) provided a qualifying statement indicating that their calculations assume that all fires are of equal intensity over the seasonal cycle. However they recognise that fire intensity is variable and proposed to refine their analysis by a stratification of fire-induced heterogeneity by season and also refine their spatial correlates with landscapes features such as stream order.

Morgan *et al.* 2001 provided a good review of fire regimes to compliment the previous summary, which has focussed on Australia information. A extract is provided in the Appendix 3. Their report includes the following paragraphs that provide an important message.

There are no adequate spatial descriptors for fire regimes. No definition or descriptor of fire regime is independent of scale, but frequency data are especially scale-dependent (Arno and Peterson 1983; Simard 1991), while fires and fire effects are variable over both time and space….. To be ecologically meaningful, the temporal scale should be chosen based upon life history of organisms affected (Clark et al. 1996); most often one to several times the life span of long-lived seral trees is used (Agee 1993; Lertzman et al 1998).

Variability and heterogeneity in fire regimes are seldom quantified. Yet they have profound implications for the ecological effects of fire, and our ability to infer and understand fire regimes themselves, especially over large areas and long times (Keane et al. 1990; McKenzie et al. 1996b; Lertzman et al. 1998; Schmoldt et aL 1999). Further, we must understand the three kinds of heterogeneity in fire regimes identified by Lertzman et al. (1998): internal heterogeneity of individual fires, and both the spatial and temporal heterogeneity of fire regimes (Morgan *et al.* 2001; p.337).

- **Review of flora / fauna studies associated with species response to fire. Most studies have focused on spinifex landscapes in conservation and Aboriginal land. Studies in pastoral areas have associations with burning to reduce woody thickening.**

A good overview was provided by Woinarski (2001b) in Whitehead *et al*. (2001). A copy of section 2.6, Trends in the distribution, abundance and condition of fire-sensitive plant species and communities in provided in Appendix 4. Efforts to expand this work are required.

Studies within and beyond the rangelands have contributed information to this area, primarily from observations associated with a single fire event. However, for the majority of species the direct effect of a single fire remains uncertain. The direct effect of multiple fires and varying fire regimes is even less certain. The opportunities for field sampling areas with contrasting fire regimes remains limited due to the restricted fire history databases described in the previous section. As a priority, an evaluation and analysis of the fire history databases should be undertaken to identify areas of opportunity for flora and fauna studies in similar environments with varying fire regimes.

Recent work by Yates and Russell-Smith (submitted) addressed fire regimes and vegetation sensitivity analysis using plant species response to fire in combination with landscape characteristics and a 10 year Landsat-based fire history. The results have showed that the majority of critical fire-sensitive species are restricted to rugged sandstone features of the landscape, but that current fire regimes characteristics, principally associated with short intervals between fires are reducing the longterm viability of the populations.

The work by Yates and Russell-Smith (submitted) relied significantly on databases of fire responses of plant species compiled by a collection of experienced botanists. Gill and Bradstock (1992) described the need for and development of national databases. Further investigation is required into the status and availability of these databases and the opportunity to link these databases with the available fire history information.

- **General Summary**

The potential for fire regime information within biodiverstiy monitoring programs is greatest in the tropical savanna ecosystems where climate and rainfall contribute to a regular production of biomass and a relatively high fire frequency. For the majority of the semi-arid and arid rangelands under pastoral production the potential contribution is much less due to the infrequent fires and the lack of fire history information, however there is some potential in the south part of the NT where a fire history database exists. For the extensive areas of Aboriginal land (or land under claim as in WA) fire is a more common feature, especially in recent times following the outstation movement and the increasingly dispersed population. These areas are characterised by spinifex grasslands, a minimal history of pastoral activity, an increasing impact of feral animals, including cats, foxes and most recently camels, and a mobile human population willing to burn country. A good fire history database only exists for the southern half of the NT, however there is the potential to develop a fire history for the past 22 years (post 1979 establishment of the Australian Landsat receiving station). The AGO Landsat time series has very significant potential for this task. Unfortunately there are significant gaps in the coverage which correspond to the large areas of Aboriginal land. Nevertheless, it is recommended that a project be developed with AGO support to undertake the compilation of an extensive fire history. A map of the areal extent of this database will be prepared prior to the workshop.

AVHRR derived fire history databases do not have sufficient accuracy to be linked to point-based ground survey data. At best the registration accuracy of each AVHRR image used to generate fire history data is +/- 1-2 km. Each pixel within an image is collecting information over a 1 km^2 area and therefore the delineation of fire edge from AVHRR images are inexact. Masters et al. (1997) tried to use AVHRR fire history information in the Tanami Desert and found that it was not sufficiently accurate for their modelling of mulgara distribution, whereas Landsat-based fire history more accurately reflected their on-ground observations of fire history and time since fire at their survey sites.

Nevertheless, AVHRR fire history provides a valuable insight into the regional fire patterns within Australia. The new MODIS sensor on the Terra and Aqua satellites has similar orbit and image characteristics to AVHRR enabling regional monitoring, but has 250m resolution which will improve the accuracy of future national fire history databases.

Global fire databases are also being compiled, linked to greenhouse studies associated with biomass burning issues. To date the databases are in the development and verification stage. Two databases, each for the year 2000, provide monthly information on the areal extent of fires in Australia. Unfortunately neither dataset seem to adequately reflect areas burnt, but further refinement and validation is in progress and provide future opportunities.

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Appendix 1. Fire history datasets within the rangelands of Australia

Northern Territory

The NT has the most comprehensive fire history database in Australia. Analysis of portions of the dataset have contributed to many scientific publications. There is a dramatic contrast in fire as a feature of the landscape between the tropical savannas of the Top End and the semi-arid to arid regions of central Australia, and the 2 regions will be described separately.

Top End

The first fire history database for the Top End was compiled for Kakadu NP from Landsat images (Press 1987). It has been maintained and refined and is complete for the time period since 1980. Similar fire history databases have been prepared for other large National Parks in the Top End (Gregory, Nitmiluk, Litchfield) using 3 Landsat images per year to record the early, middle and late dry season fires. These dataset have been compiled for the period since 1990 and have a spatial resolution based on the 30m² satellite pixel. There are known omissions in the data associated with cloud obscured late dry season and wet season fires.

A second fire history database based on NOAA AVHRR satellite images covers the whole Top End region for the period since 1993. The spatial resolution is based on the 1 km² satellite pixel, with a 9-day update schedule (unless obscured by clouds) based on the repeat cycle of the satellite. There is potential to calculate numerous fire regimes metrics, with information available on season of fire (at its simplest EDS and LDS), plus minimum fire interval, and mean fire interval.

Table 1. Top End NT fire frequency 1993 to 2001

Fire frequency	Area (km²)	%_TopEnd
0	68223.5	13.1
1	103242.3	19.8
2	109419.3	21.0
3	85654.0	16.4
4	58572.0	11.2
5	37000.0	7.1
6	26422.5	5.1
7	18284.5	3.5
8	10968.5	2.1
9	4013.5	0.8
Total	521800.0	100.0

Central Australia

The central Australia fire history database was initially compiled from Landsat images for the period from the mid-1970s to 1985 and covered the area of the NT south of –20°. Subsequent updates of the database (1986 to the present) used NOAA AVHRR images. Several small areas of Landsat-based fire history exist within central Australia. The most comprehensive is associated with Uluru NP (1950 to the present), but an area of the Tanami Desert also has a Landsat based fire history (1979-1994).

Tables 2 and 3 provide a few simple summaries for central Australia, using time periods for fires rather than individual years. This reflects periods of fire activity and database characteristics. For the fire frequency table, it assumes that fires within each time period did not overlap spatially. There are few instances where fires are known to have burnt the same area twice within the time interval, but the areal extent is small and has minimal effect on the general proportions.

Table 2. Period of Last Fire

last fire	area (km²)	%_Cent-Aust
Unburnt	191931.7	31.3
1999-2002	196893.3	32.1
1986-1998	80879.8	13.2
1979-1985	43791.6	7.1
1972-1978	99104.0	16.2
	612600.4	

Table 3. Fire Frequency

Fire frequency	area (km²)	%_Cent-Aust
0	191931.7	31.3
1	191832.9	31.3
2	163803.9	26.7
3	62030.3	10.1
4	3001.6	0.5
	612600.4	

Within central Australia, 31.3 % has no mapped fire history. This includes many areas which were burnt during the mid-1970s but the spatial extent of the fires and the time of their occurrence is unrecorded although some descriptive accounts from land managers in combination with archived fire reports from Bushfires Council NT may be of some use. However the difficulty is to find time and resources to undertake the work. The result is that 47.5 % of central Australia has not had a mappable fire for greater than 25 years. The majority of this area are the pastoral lands where the greatest impact of cattle has occurred. Tables 4 to 7 stratify the previous information into the areas of pastoral and aboriginal land and highlight significant differences associated with land tenure.

Table 4. Period of Last Fire for Pastoral Lands in Central Australia (south of –20°)

Pastoral		
last fire	area (km²)	%_Tenure
Unburnt	136253.4	50.8
1999-2002	70941.4	26.4
1986-1998	10918.3	4.1
1979-1985	7728.1	2.9
1972-1978	42625.9	15.9
	268467.1	

Table 5. Fire Frequency for Pastoral Lands in Central Australia (south of –20°)

Pastoral		
Fire frequency	**area (km²)**	**%_Tenure**
0	136253.4	50.8
1	85085.6	31.7
2	37966.3	14.1
3	8842.0	3.3
4	319.9	0.1
	268467.1	

Table 6. Period of Last Fire for Aboriginal Lands (includes VCL and CLP) in Central Australia (south of –20°)

Aboriginal		
last fire	**area (km²)**	**%_Tenure**
Unburnt	52127.3	15.5
1999-2002	124231.7	36.9
1986-1998	69108.4	20.5
1979-1985	35641.6	10.6
1972-1978	55696.4	16.5
	336805.4	

Table 7. Fire Frequency for Aboriginal Lands (includes VCL and CLP) in Central Australia (south of –20°)

Aboriginal		
Fire frequency	**area (km²)**	**%_Tenure**
0	52127.3	15.5
1	103821.1	30.8
2	125011.8	37.1
3	53163.4	15.8
4	2681.8	0.8
	336805.4	

Western Australia

Department of Land Administration (DOLA) has compiled the following AVHRR-based fire history datasets.

Kimberley region: since 1993
Whole of WA: since 1995
Whole of Aust.: since 1997

There is an interest to extend the projects back in time, but finding sufficient funds and interested and skilled image processors is a difficulty. The Kimberley region is part of north Australia's tropical savanna region and its fire history and frequency is not dissimilar to NT's Top End, with

a relatively high proportion of the region having a suitable fire frequency for the calculation of numerous suitable fire regime metrics.

Table 8. Kimberley WA fire frequency 1993 to 2000

Fire frequency	**Area (km²)**	**%_Kimberley**
0	57814.5	15.4
1	105479.0	28.1
2	97272.8	25.9
3	63581.5	16.9
4	32964.5	8.8
5	13252.8	3.5
6	4001.0	1.1
7	922.0	0.2
8	176.3	0.0
Total	375464.3	100.0

For the whole of WA and the whole of Australia, the short time frame of the datasets limits their application to fire regime calculations. The whole of Australia dataset was initiated through the State of Environment reporting process.

The NHT-funded Kimberley Fire Management project includes a Landsat-based fire history mapping component, using both images and quicklooks. For the Kalumburu full scene.(108/70) a fire history for the period 1990-2002 is being developed using 3 scenes /year. A fire history for 2001 was prepared from Landsat ¼ scenes for 3 areas representing major landscape types of the Kimberley, that are also the location of field-based vegetation and fauna surveys. The areas are:

Pindan Vegetation	110/72	Beagle Bay peninsula
Open Eucalypt Vegetation	108/71	Mt Elizabeth
Spinifex Communities	108/73	Bohemia Downs

In addition, for the

Rocky Sandstone Country	109/71	Bachsten Creek

the project will purchase 3 full scenes / year to map the fire history for 1998 to 2002. In addition one year's data, representing an average fire year based on the Kimberley 1993 – 2002 AVHRR-based fire history will be used to assess internal fire patchiness.

Conservation and Land Management (CALM) have indicated that their long-term fire history datasets are only within the southwest forests, beyond the rangelands area. The associated fire history information for both wildfires and control burning programs began in the 1930s. There is almost no other information, but several recent projects are being to collect data. A project in the Pilbara region in 2001-2002 purchased 19 Landsat scenes as part of a collaborative project between CALM and FESA. A component of the project investigated the mapping of fires with Landsat and to improve the understanding of the landscape characteristics causing errors in DOLA's fire mapping with NOAA AVHRR images. However it was described as a once off joint effort, but there are plans for future work, including pasture and fuel load assessment based on the landsat images to contribute to better fire management planning in the region.

Two other isolated areas within the desert regions of WA have fire history information which has been analyzed. Unfortunately neither dataset is current and further mapping and analysis would

be very valuable. The first is an area of Gibson Desert in central east WA which was used to compare and contrast a change in fire patterns from the last 1950s with the late 1970s (Burrows and Christensen 1990). The early period represented an active Aboriginal burning pattern, associated with a remnant of the Aboriginal population still living a nomadic hunter-gatherer existence. The latter period followed the end of Aboriginal occupation and was characterised by extensive wildfires during the mid 1970s period of above-average rainfall across inland Australia. Unfortunately no subsequent data has been collected to follow the subsequent changes associated with the outstation movement and increased access and travel through the region.

The second is an area of Great Sandy Desert with fire history for the period 1972 to 1994. The study area was the extent of a single Landsat scene (108/80 - possibly 107 / 80). The area also covered the reptile collection and study sites of Eric Pianka. The first compilation and analysis of the fire history was a Master's thesis (Curry 1996). Further analysis by Haydon et al (2000) used the 1972 to 1991 images to describe fire shape characteristics. Contact for the dataset and project information would be through Melba Crawford, University of Texas (http://www.csr.utexas.edu/projects/rs/aussie.html).

New South Wales

The only databases in rangelands are in far west parks and reserves as derived by Andrew Willson. Other databases by Peter Brookhouse in Coonabarabran office for Pilaga and Warrumbungles, and by Margaret Kitchin PhD thesis based on Guy Fawkes River National Park are beyond the rangelands area. For the majority of western nsw the only recent fires were in the mid 1970s but experience from Andrew Willson was that the fire extents are difficult to map, due to lack of landsat images and air photos and made difficult by fading and inaccurate memories. Info on fire history in mallee region dates back to 1920s fires, but spatial extents are descriptive rather than explicit.

The fire history databases for the area of far west NSW only cover the conservation reserve areas, although $12,000 worth of images for the NSW/VIC/SA mallee region was purchased by NSW NPWS two years ago. The images have been processed for the NSW reserve areas only, however the Vic NRE Parks have processed the images to derive a fire history for the Murray–Sunset region of northwest Vic. Contact for the Vic databases is Mike Wouters NRE Parks in Mildura (03)5022-4355. However the area is outside the rangelands area defined by the National Land and Water Audit. With the exception of small mappable fires in recent years, the big fire event was in 1974-75 when large fires burnt through the mallee region. The fire perimeters are readily mapped in the mallee area but unmappable in the other lands and anecdotal records are useful but not accurate. In the Scotia / Dangalli region unburnt mallee are estimated to be unburnt from at least the 1917-1918 fires. There are a few spots with 100+ year old unburnt mallee communities; an area of 50-60,000 ha halfway between Euston and Balranald is a very old community, obvious from its vegetation structure and has known populations of possums and malleefowl.

The region has a fairly simple fire regime due to the absence of fires, the modified landscape and the inconsistent fuel loads. Years with fuel loads are well recorded, and in other years the fire risk is very low due to the discontinuous fuel loads.

A proposal has been submitted for a position through NSW Dept of Land and Water to undertake the compilation of fire history dataset for the region.

Queensland

QDNRM indicated that fire mapping in Laura basin (Landsat scene 97/70) was a test site and a fire history database was not developed. Their current focus in on NOAA AVHRR images to develop an automated mapping approach which would allow them to develop a AVHRR-based fire history for Qld from 1984. Their work program is addressing BDRF (bi-directional reflectance) issues within AVHRR images as a precurser to mapping fires. Schedule is to complete the process over the next 1-2 years. The Cape York project is developing a Landsat-based fire history, plus have just begun extending it into the Gulf country. They will create a fire history for northern savanna regions of Qld.

For many of areas of arid Qld fire has largely been removed from the landscape, especially in mitchell grass landscapes. However the hotspot datasets in the central Qld areas with small properties is showing that fires are occurring in those areas, but at too small a scale for detection with AVHRR images. There has been significant amounts of fires occurring during the past 1-2 years due to the good seasons. Qld has incorporated the hotspot datasets into their SoE reporting as an indicator of fire occurrence / fire frequency, but with lots of caveats on its interpretation. This identifies a need for intensive scrutiny of fine resolution images to identify and map small fires in these areas, using the hotspots as a guide to the search, plus it would also require information and reporting from land managers and fire agencies.

A project on Cape York has mapped fire history from Landsat quicklooks for 4 Landsat scene areas (97/70-71 and 98/69-70) on Cape York area the period of 1999 to 2002. Data is distributed to land managers for their info and the project doesn't plan to extend the fire history back in time. A new project in the gulf region is extending the database further south, but not west. Area covers 7 Landsat scenes including 98/71-73; 97/72-73 and 96/72-73. Fire data started in 2002 and will continue, but there is uncertain about developing a fire history. The project will include the Laura Basin Landsat scene (97/70)images and the fire history from Cesar Rodrigez's project for the period 1987 to 2003. Virginia cooper is responsible for extending the work to 2003, but didn't discuss the need to verify Cesar's previous work.

Qld Parks do not have longterm fire history data available for majority of parks, and have been using data from Virginia Cooper. Two small parks on Cape York have compiled fire history information on the basis of experience and memories of longterm rangers. A recent meeting prepared a fire management strategy requiring rangers to document and prepare spatial data on all fires in the future, but there was not a directive to review and map past fires. The initial work by Earl Saxon (in the late 1980s) to develop a fire management program at Lakefield NP does not seem to have progressed.

South Australia

The primary fire history datasets are only for a few national park areas, such as Kangaroo Island, and are primarily outside the rangelands area. Other work includes a fire risk program and datasets but the areal extent is restricted to Adelaide hills region.

Appendix 2. Contacts for Australia fire dataset information

NT

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NSW

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Peter Brookhouse	

Vic

Mike Wouters	03-5022-4355

Qld

Lisa Collett	07-3896-9529
Virginia Cooper	07-4031-3432
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WA

Belinda Heath	08-9387-0330
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SA

Jeff Foulkes	08-8124-4722
Mike Williams	
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Appendix 3. Extract from Morgan *et al.* 2001

Fire regime refers to the 'nature of fires occurring over an extended period of time' (Brown 1995). Fire regimes reflect the fire environment, and influence the type and abundance of fuel, thereby affecting fire behaviour and fire effects through time.

Fire regimes can be described by

frequency,
magnitude (severity and intensity),
predictability,
size,
seasonality, and
spatial patterns.
(Heinselman 1981; Pickett and White 1985; Agee 1993; Crutzen and Goldammer 1993).

The **frequency of fires**,

expressed as fire return interval,
probability of occurrence, or
rotation period,

is the number of fire events at a point (point frequency) or within a specified area (area frequency or rotation period) and a time period, or period of record.

Point fire frequencies, like

mean fire interval (Heinselman 1973; Agee 1993) or
Wiebull mean fire interval (Johnson 1992; Finney 1995; Grissino-Meyer 1999)

are explicitly spatial, but represent spatial patterns as aggregates of point samples.

Fire rotation period and fire cycle,

incorporate reconstructed or mapped fire perimeters, and are defined as the length of time necessary to burn an area equivalent to a specific study area or landscape (Heinselman 1973; Agee 1993; Johnson and Gutsell 1994).

Fire cycle is distinguished from fire rotation in that it

is calculated based on the distribution of ages in a time-since-fire map (Johnson and Larson 1991; Johnson and Gutsell 1994).

Fire cycle and fire rotation period

incorporate both the extent and frequency of fires.

This is the main distinction between fire regimes described using

mean fire frequencies and
fire rotation periods.

The frequency of fires directly and indirectly affects species life cycles, vegetation structure and composition, and fuel accumulation and is the main theme of much research involving the evaluation of fire regimes.

Fire intensity and severity describe the behavior and effects of individual fires.

Fire intensity

is a physical description of fire behavior, and
is defined as the amount of energy released by a flaming front, and.

is closely correlated with flame length (Albini 1976).

Fire severity
is broadly defined as the degree of ecosystem change induced by fire (Ryan and Noste 1985).

Fire severity has been described by
the degree of tree mortality (Agee 1993; Morgan *et al.* 1996),
heat penetrating into the soil (Lea and Morgan 1993),
degree to which fires consume organic biomass on and within the soil (Lenihan *et al.* 1998),
change in color of ash and soil (Wells *et al.* 1979; Ryan and Noste 1985), or
a combination of these fire effects (Turner *et al.* 1994). …..

Fire frequency and severity are most often used to classify and map fire regimes (Heinselman 1973, 1978, 1981; Morgan *et al.* 1996; Hardy *et al.* 1998a, 1998b, 1999; Brown and Smith 2000). For mapping fire regimes, severity is typically defined based upon degree of mortality in overstory vegetation-even where the dominant overstory is shrubs (in shrublands) or grasses (in grasslands).

Appendix 4. Extracts from Whitehead *et al.* 2001

Background Paper I : A Review of Changes in Status and Threatening Processes By John Woinarski

Woinarski J (2001) Background Paper 1. A Review of Changes in Status and Threatening Processes. In: Whitehead P, Woinarski J, Fisher A, Fensham R, Beggs K. Developing an analytical framework for monitoring biodiversity in Australia's rangelands. A report by the Tropical Savannas CRC for the National Land and Water Resources Audit. Tropical Savannas CRC, Darwin NT. Pp 71-310.

5. Threatening Processes

Rangeland biodiversity is affected by many factors, with the intensity of this impact varying between different regions and different components of biodiversity. As monitoring schemes may find it easier to report on the threatening processes rather than the responses of biodiversity *per se* (Saunders et al. 1998), it is important that linkages can be established between measures of the threat and responses of the biota, and that an assessment of the relative impacts of different threatening processes can be made and used to prioritise monitoring actions. In this section, we briefly review the main threats considered to affect rangeland biodiversity. While each potentially threatening process is considered separately, it is important to recognise that, at any site, typically a number of processes may be operating together with compounded or complex interactive effects.

5.1 Changed fire regimes

While fire clearly has a major role in structuring rangeland ecology, the derivation, designation and imposition of appropriate fire regimes has been a deeply vexed and controversial issue (Flannery 1994; Langton 1998). It is indisputable that Australian rangeland environments were shaped by the use of fire by Aboriginal land managers over tens of thousands of years, and that when this management was usurped, many of those rangeland environments were remoulded (Hallam 1985). Change form the traditional fire regimes will have benefitted some components of biodiversity and disadvantaged others. The extent of the resulting change in biodiversity is probably loosely correlated with the extent of change in the fire regime. Such a relationship may allow the extent of change in fire regime to provide some surrogate of likely changes to biodiversity (Saunders *et al.* 1998), especially where the current regime can be well described and mapped (Press 1988; Russell-Smith *et al.* 1997; Crowley and Garnett 2000). However, the utility of the index is substantially compromised if there is a problem in determining what the pre-European fire regimes were for many rangeland areas (Fensham 1997; Bowman 1998).

Very coarsely, most evidence supports the notion that Aboriginal management involved relatively frequent fine-scale patchwork burning (Bolton and Latz 1978; Kimber 1983; Griffin 1984; Braithwaite and Estbergs 1985; Burbidge 1985; Low 1986; Bowman and Panton 1993; Price and Bowman 1994), with fires deliberately lit for a broad range of reasons (Hallam 1985; Lewis 1985). The intricacy of the mosaic, and the return time between fire events, is likely to have varied across rangeland areas, in relation to underlying topographic complexity, human population density, abundance and type of food resources, climate and rainfall events pre- and post-fire (Hopkins 1985; Hallam 1985). This patterning has now been replaced across much of the rangelands by one of two regimes: either attempted fire exclusion (particularly in areas of greatest intensity of pastoral use, where livestock may reduce fuel loads so much that fires

cannot be established anyway), or abandonment of any attempt to maintain a fire regime (particularly in remote and sparsely inhabited areas, where relatively long periods without fire may be interrupted by occasional extensive hot fires, usually caused by lightning strike) (Lewis 1985; Dyer *et al.* 1997; Noble 1997; Bowman 1998). These regimes each have distinct ecological consequences.

Deliberate exclusion of fire has led to extensive changes in vegetation in the grazing lands of western New South Wales, western Queensland and in parts of northern Australia. The most marked manifestation of this change in fire regime is a major increase in the density of trees and woody shrubs the "woody weed" problem), typically at the expense of grasslands and open woodlands with savanna understoreys (Rolls 1981;Wright 1981; Noble 1997). Less conspicuously, fire exclusion has probably also reduced local- and regional-scale environmental heterogeneity. The impacts upon fauna of this broad-scale change in vegetation structure and patchiness have not been comprehensively assessed, and may be difficult to disentangle from those due to other factors which typically coincide with fire exclusion (most notably intensive pastoralism). Nonetheless, such extensive and substantial changes in vegetation would clearly be detrimental to at least the fauna reliant on grassy understoreys and open woodlands. The limited available evidence suggests that birds associated with such habitats have suffered substantial declines across these rangeland areas (Franklin 1999).

Reversion to the "natural" fire regime (no or scarce ignitions by humans, but occasional extensive wildfire) has had major impacts on the environments of some remote rangeland areas (Griffin *et al.* 1983). In the Tanami Desert, this regime has led to loss of.intricacy in the environmental mosaic, probably to the cost of the mala *Lagorchestes hirsutus,* now extinct on the mainland (Bolton and Latz 1978; Lundie-Jenkins 1993). Across much of the rangelands, it has led to decline in the extent of fire-sensitive vegetation. In central Australia, the most conspicuous response has been the contraction in range of mulga communities and the expansion of hummock grasslands (Fox 1985; Bowman *et al.* 1995).

Increasingly severe fire regimes (greater frequency of extensive hot fires) have been reported for parts the wet-dry tropics of northern Australia, where frequent fire is almost inevitable. For current fire regimes, intervals between fires are now insufficient to maintain some plant species, particularly those which reproduce as obligate seeders (Bowman and Panton 1.993; Price and Bowman 1994; Russell-Smith *et al.* 1998), animals associated with those plant species (e.g. the Leichhardt grasshopper *Petasida ephippigera:* Lowe 1995), or animals requiring large hollow trees, fallen hollow logs and/or a dense tall shrubby understorey (e.g. brushtall possum *Trichiosurus vulpecula* and black-footed tree-rat *Mesembriomys gouldii:* Kerle 1985, 1998; Friend 1987). In these areas, current fire regimes are now also leading to the diminution and deterioration of patches of fire-sensitive environments, most notably monsoon rainforests (Clayton-Greene and Beard 1985); McKenzie and Belbin 1981; Russell-Smith and Bowman 1992).

Hence, across broad landscapes, the current fire regimes have led to changing juxtaposition and relative extent of contrasting vegetation types. They have also changed characteristics *within* most vegetation types, altering vegetation structure and floristic composition over very large areas.

In the open forests dominating the landscape of higher rainfall areas of northern Australia, several studies have examined the response to fire exclusion, in locations where there has been a massive effort spent on ensuring fires do not enter small selected areas. These studies have

documented floristic and more marked structural changes (Bowman *et al.* 1988; Fensham 1990) but they are not of sufficient magnitude nor do they represent clearly desirable or readily achieved management options. However, impacts of fire will be far more pronounced following the proliferation and spread of improved pasture grasses, such as mission grass *Pennisetum polystachion* and gamba grass *Andropogon gayanus,* which provide far greater fuel loads, and which cure far later in the dry season (Panton 1993; Bowman 1999).

Because many plant and aninial species have distinct associations with, or dependence upon, resources available only at particular time spans after fire, the full range of biodiversity potentially present within any environment will only be maintained when a broad range of fire histories are locally or regionally available. For example, for hummock grasslands, some *Triodia* species are obligate seeders while others are resprouters. There seems to be little consistent geographic pattern in these response categories, although the patterns of abundance of the obligate seeders can be profoundly affected by fire regime (Rice and Westoby 1999). Many ephemeral plant species are abundant only in the first few years after in spinifex (Bowman *et al.* 1990; Griffin 1991) and the longterm persistence of these species may well be dependent on at least occasional fire. On the other hand for the sandstone ranges and plateau in the monsoonal regions of the Northern Territory, there are a number of species that are clearly sensitive to very frequent fire regimes. Shrub species such as *Regelia punicea* are poorly dispersed obligate seeders and may take up to 10 years to become fertile. Clearly frequent fires will have a detrimental affect on the abundance of this species, and others with similar life histories (Russell-Smith *et al.* 1998).

In mallee vegetation in the southern rangelands, there is a well established "succession" of bird species with increasing time since fire, from widespread opportunists (including nankeen kestrel *Falco cenchroides,* australian magpie *Gymnorhina tibicen*) less than 1 year post-fire, to species associated with low patchy heathlands (including chestnut quail-thrush *Cinclosoma castanotus,* white-fronted honeyeater *Phylidonyris albifrons,* shy heathwren *Hylacola cauta*) at 1-10 years post-fire, to species associated with taller denser, heaths and low woodlands (including red-lored whistler *Pachycephala rufogularis,* southern scrub-robin *Drymodes brunneopygia,* and crested bellblrd *Oreoica gutturalis*) at 10-30 years post-fire, to species associated with taller woodlands, denser litter layers and hollows (including malleefowl *Leipoa ocellata,* white-browed babbler *Pomatostomus superciliosis,* black-eared miner *Manorina melanotis,* and regent parrot *Polytelis anthopeplus*) at more than 30 years post-fire (Woinarski 1999). Analogous sequences have been described for mammals and reptiles in hummock grasslands in the arid and semi-arid rangelands (Masters 1993, 1996; Reid *et al.* 1993), and are undoubtedly replicated by other groups of biota in other environments. A regional fire regime which results in the retention of only one of these stages will eliminate many species and homogenise the landscape (Woinarski and Recher 1997; Woinarski *et al.* 1999b).

But the retention of all types of regimes will not necessarily maintain all species, as connectivity between patches of particular ages may also need to be maintained, and the juxtaposition of patches of contrasting history may also be critical for some species which prefer old vegetation for breeding but younger regrowth for foraging, or which require access to patches of different ages in order to maintain resource availability across different seasons (Carpenter and Mathew 1986; Priddel 1989, 1990).

Fire regimes are more than simply about frequency or periodicity. Other components such as the extent of fire, the seasonal timing of fire, the amount of rainfall before and after fire, and the

intensity of fire may be critical in determining their ecological effects (Gill *et al.* 1981; Gill 1999).

The maintenance of a particular fire regime is a critical requirement for the persistence of many rangeland plant and animal species. For example, Garnett (1992) listed inappropriate fire regime as a threatening process for 51 threatened birds in Australia, of which 35 are rangeland taxa.

A Manual for Biodiversity Monitoring
By John Woinarski

Woinarski J (2001) A manual for biodiversity monitoring. In: Whitehead P, Woinarski J, Fisher A, Fensham R, Beggs K. Developing an analytical framework for monitoring biodiversity in Australia's rangelands. A report by the Tropical Savannas CRC for the National Land and Water Resources Audit. Tropical Savannas CRC, Darwin NT. Pp 463-485.

2.6 Trends in the distribution, abundance and condition of fire-sensitive plant species and communities

[this element is related to Products 5 (Change in composition of perennial plant species and abundance of selected invasive, fire sensitive and grazing sensitive species) and 12 (Extent, timing and frequency of fire) of the Audit's *Operational Manual.*]

Remote sensing (mostly using interpretation of NOAA-AVHRR and/or LANDSAT imagery, depending upon the scale of resolution demanded) is now being used routinely to monitor fire occurrence across the rangelands of northern Australia, and to report on the extent, timing and frequency of fire by bioregion and by vegetation types (e.g. Russell-Smith *et al. 2000).* The procedure is suitable for extension to include monitoring across the entire rangelands (Wallace and Campbell 1998), which would allow annual reporting (by environment, bioregion, and at jurisdiction and national scales) of the proportion of lands burnt, of the proportion of lands of varying ages since last fire, and of varying fire frequencies.

It is evident that some species (such as northern cypress-pine *Callitris intratropica:* Bowman and Panton 1993), groups of species (such as those heathland plants which reproduce only as obligate re-seeders: Russell-Smith *et al.* 1998), or environments (such as rainforest patches, mulga woodlands and chenopod shrublands) are particularly intolerant of some fire regimes. While the fate of these can be inferred from remote-sensed monitoring of fire patterns generally, this inference may initially be weak. We suggest that for each main rangeland environment and/or bioregion, natural resource management agencies should nominate one or several species or species-groups which best represent these fire-sensitive plant species or groups, and that targetted monitoring programs then be established specifically for such taxa. Such programs should aim to relate fire regimes to the abundance and population structure of these plants, using sampling in plots established across their distribution and representing the range of land-uses or management regimes operating. Wherever possible, this sampling should include existing pastoral monitoring plots.

Such programs may need to be relatively species-specific, and hence general monitoring protocols cannot readily be defined.

Fire-sensitive plant species or communities represent only one extreme of responses to fire regimes. The decline of these is often counterpointed by increases in other species or communities. The most notable such examples are the increase in native "woody weeds" in generally grazed and infrequently burnt rangeland areas of eastern Australia (e.g. Noble 1997). It may be as important for biodiversity monitoring in the rangelands to keep track of such increases and environmental dynamism. Some measure of such change should be extractable from the existing pastoral monitoring plot network, although the sampling intensity may need to be increased in some environments or bioregions through supplementation with additional long-term plots (e.g. Burrows *et al.* 1998). The plot-based monitoring should be complemented by use of remote-sensing to detect landscape-scale changes in tree or shrub cover (Wallace and Campbell 1998).