Fire Patterns in semi-arid woodlands and shrublands of southern Western Australia

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Abstract

During the summer and early autumn months of 1991 wildfires started by lightning storms burnt an area of some three quarters of a million hectares of semi-arid woodland and shrubland in the Ravensthorpe, Esperance and Dundas Shires. To place this event in an historical context, the fire history since about 1950 was compiled for the Lake Johnson and Malcolm 1: 250 000 map sheets using black and white air photographs and LANDSAT imagery. During the four decades of the study period a number of large fires (<100 000 ha) occurred in both areas; however, substantial areas of the landscape also remained unaffected by fire. Some areas were burnt several times during the period, with fire intervals as short as eight years. Fire ages estimated from remote sensing were cross-checked by counting annual growth rings on stem sections from *Callitris* trees. This species is slow-growing and long-lived, and it is very likely that the chance sequence of past fires has strongly influenced the present-day distribution and extent of *Callitris* stands. Evidence to support this proposition can be found in the form of distinct vegetation boundaries which coincide with the boundaries of previous fires, and in the form of dead *Callitris* stems in areas some distance from the nearest live populations. The regeneration ecology of *Callitris* in southern Western Australia would be an interesting and worthwhile topic for further research.

Introduction

During the summer of 1991, wildfires started by lightning burnt an area of some three quarters of a million hectares of bushland in CALM's Esperance District. Most of the area burnt was shrubland or semi-arid woodland. Because these fires burnt in areas remote from farms and settlements, they were largely left to burn unchecked. However, some back burning and scrub-rolling operations were undertaken along the interface between bushland and farmland to minimise the threat to property assets.

Large fires started by lightning are not an uncommon event along the south-coast east of Albany and in the hinterland which extends inland for several hundred kilometres. In fact, only 12 months before, fires caused by three separate lightning strikes had burnt about 100 000 ha of the Fitzgerald River National Park in a period of about 10 hours. During the decade of 1980's major fires also occurred as a result of lightning at Cape Arid in 1981 and 1983 and at Fitzgerald River in 1985.

However, the fires of the early 1991 were on a scale which well and truly exceeded anything that had occurred in recent times. At the time, the main area of research for myself and offsiders Bob Smith and John Neal was the behaviour of fires in mallee-heath and associated shrublands. While a substantial proportion of the area burnt was in fact semi-arid woodland, the general character of the fuels and vegetation, and of the weather patterns which governed the spread of fires provided a rare opportunity to investigate the spread of fires in a landscape little affected by human influences.

To place the fires of 1991 in an historical context, albeit a relatively short one, we set out to study the fire history of two representative areas of the South-Coast Region since about 1950. This date was chosen because it represents the earliest date at which fires could reliably be mapped from broadscale air photography.

The two areas chosen for study were:

(1) the Lake Johnson 1:250,000 map sheet which covers the country east of the State Vermin Barrier fence across to the agricultural lands around Salmon Gums and the mining tenements of Norseman. This area includes two important National Parks vis Frank Hann and Peak Charles with the remainder mostly Vacant Crown Land.

(2) the Malcolm 1:250,000 map sheet which includes the Cape Arid National Park, a substantial area of Nuytsland Nature Reserve, and Vacant Crown Land.

For reference purposes each map sheet includes an area approximately 140 km x 110 km, equivalent to 1.54 million ha.

Aims of the study

The principle aim was to document the extent of fires in the landscape at each study area since about 1950 in order to identify the range of fire frequency experienced. In particular, we were interested to identify areas burnt several times during this period.

Information about relative frequency of fire could then be used to test hypotheses regarding

(1) whether some vegetation types are more prone to fire than others.

(2) the effect of fire, particularly repeated fires, on the structure and floristic composition of plant communities.

Although CALM has only quite limited resources available for fire management in remote semi-arid areas, information about the extent of fire and its impacts is important for several reasons. These include (1) assessing the need for and effectiveness of pre-suppression actions such as prescribed burning of strategic buffer zones (2) providing a basis for deciding what level of intervention, if any, should be undertaken to modify or contain the spread of wildfires (3) monitoring the condition of ecosystems as a baseline for future management.

Methods

Fire scars were identified from black and white air photographs and satellite imagery of each study area. The earliest air photography available for each entire map sheet dated from March 1958 in the Lake Johnson area, and December 1962 in the case of the Malcolm study area. This early photography was in the form of photomosaics compiled from individual photographs, and there was considerable variability in the clarity and tone of the resulting mosaics. Despite this, relatively recent fires (defined as within 10 years of the date of photography) could be readily identified and mapped. Mosaics were at a scale of 1: 63 360.

Further black and white air photographs taken in 1971 were available for both study areas. Although not compiled into mosaics these photographs were considerably better quality than their earlier counterparts.

Colour LANDSAT imagery was available from about 1975 onwards at a variety of scales.

On some of the early photo mosaics it was very difficult to distinguish the condition of the vegetation from the tone, usually because of variation in the underlying geology and landform. This was particularly the case in the eastern and north-eastern sections of the Malcolm study area where there are extensive parallel dunes. Such areas were considered to be uninterpretable with respect to fire history and were therefore excluded from further study.

Fire boundaries were traced on to tracing paper, together with details of important landscape features such as roads, lakes, hills and coastline which could act as tie points when overlaying information from successive imagery. Boundaries were digitised and brought to a common scale of 1:250 000 using the MICROSTATION geographic information system at CALM Manjimup, with helpful assistance of Paul Davies. Unburnt patches within extensive fires were generally only mapped if they exceeded 1 km^2 in area.

To date, the GIS has primarily been used to print maps and overlays at a common scale for manual interpretation. More sophisticated analysis is theoretically possible on the GIS but this would not be a straight forward task as some of the earlier fires had incomplete boundaries, and because of the fairly rudimentary spatial control. Despite this latter problem, there were many instances where the boundaries of particular fires were mapped from successive images and still coincided to a high degree.

Having generated broad fire history maps we then set out to validate these in the field. In the case of more recent fires (since about 1980) this task was mostly quite simple because CALM records indicated the year and cause of fire, and usually an approximate fire boundary. The task was more difficult with older fires and in areas which showed no evidence of fire within the period of study.

Fortunately, however, the native conifers *Callitris verrucosa* and *C. roei* have relatively widespread distribution within both study areas. Both species have distinct growth rings, which are almost certainly annual because of the nature of the climate in the semi-arid zone, and can be aged with reasonable accuracy. Both species are also potentially long-lived (>100 years), but having very thin bark (<5 mm) are killed outright by almost any fire. Thus, the age of the oldest living *Callitris* in a stand of vegetation is usually a reliable indicator of the minimum period for which it has been unburnt. Whether or not it actually indicates the date of the last fire depends on the assumptions made about the conditions necessary for recruitment of seedlings. Neither species is capable of resprouting after damage by fire.

Results

Malcolm study area

The 1962 photography indicated several major fires in the southern section of the study area, which from the pale tones on the photographs were estimated to have been no older than about five years. The shape of the largest fire suggested that it had taken several major runs under differing wind directions. On its longest axis this fire extended for at least 50 km.

Several of the other fires were 12-15 km long and up to 5 km wide. The discrete boundaries of these fires indicate that they had not originated from escaped agricultural clearing burns, and in most cases the relative remoteness suggest lightning, and not human activity, as the most likely cause of ignition.

There was extensive evidence of older fires on the 1962 photography, but fire boundaries could not be fully mapped as they were obscured by the more recent fire scars.

The 1971 photography revealed a further series of discrete fires, although not as extensive as those on the 1962 photography. Some limited areas up to about 5 km x 5 km in area had been burnt in the late 1950's and again prior to 1971, suggesting an inter-fire interval of ten years or so. Again, the shape and location of fires pointed to lightning as the most likely cause.

In February 1983 most of the southern half of Cape Arid National Park was burnt under severe weather conditions, with the final area of the fire around 90 000ha. This fire was initiated by lightning strike which was contained at a size of about 100 ha but the fire report prepared at the time noted possible human interference as being the cause of the second, much larger fire run. However, experience during 1991 season showed that fires could stay inactive but alive for many weeks, only to take a major run when the required combination of severe weather conditions and a favourable fuel situation was achieved.

A large fire had also burnt much of the area to the east of this in 1981.

The next major fore event was in 1990/91 when lightning ignited three fires in, or close to, the park following a series of thunderstorms in mid to late December. Two of these fires made initial runs and then went dormant. Fire #12, which was ignited north of Mt Ragged, remained dormant throughout January and February despite a regular sequence of extreme fire weather on a 7-10 day cycle this fire. This fire subsequently made a major run under northerly and then south-westerly winds to attain a final size of about 121 000 ha.

The most striking feature of Fire #12 was that it re-burnt extensively through the top of the 1983 fire, which was only 8 years old at the time. Up to 10 000 ha of mallee-heath, mallee and woodland was thus burnt twice by lightning-caused fires in relatively short succession. Brief field inspection of some of this country indicates that there may be profound and long-lasting changes in the abundance of some plants as a result of this sequence of fires, particularly for non-resprouting plants which have capsule-stored seed.

A further lightning-caused fire in October 1991 re-burnt a sizeable area in the south-east of the Park which had last been burnt in 1981.

Despite this rather torrid history of fire there are in fact sizeable areas of the Malcolm study area that have no recorded fire history since well before 1962. Limited sampling of C. roei stem sections has indicated that some of the areas adjacent to the Balladonia track have been unburnt at least since about 1940.

Lake Johnson study area

The overall extent and frequency of fires was greater in the southern half of the study area than in the northern half. As the level of access and human activity are low in both halves this difference is unlikely to reflect a higher probability of human-caused ignition in the southern half.

Photomosaics from 1958 revealed evidence of extensive fire activity throughout the study area. Separate overlays were prepared showing more recent fires (post 1950), and those that were clearly older because of the darker vegetation tones and the fact that they were overlain by more recent fire scars. As was the case in the Malcolm area, the relative remoteness of many of the fires and their apparently random pattern suggested that many were likely to be lightning ignition. Individual fire runs exceeding 25 km in length were not uncommon.

The 1971 photography did not reveal any major new fires during the preceeding 13 years, although there were a number of relatively small fires that had occurred during this period. Interestingly, some of the fires mapped as recent events from the 1958 photomosaics were still very distinct.

A very large fire (approximately 40 km long x 25 km wide = 100 000 ha) was detected from the earliest available LANDSAT imagery of 1975, and burnt much of the area adjacent to the Lake King Norseman road to the west of the Ninety Mile Tank. Ring-counts on *Callitris* stems placed the date of this fire as around 1972-73. There were a number of smaller fires of similar age further to the east, which suggests that there may have been a season or two of above-average lightning fire occurrence around this time.

Fire activity in the period from the early 1970's to 1990/91 appears to have been fairly limited, with no major new fire scars detected on the satellite imagery during this period.

However, the situation changed radically in December 1990 with at least five widely-distributed lightning-caused fires from a series of thunderstorm events in late December (14, 23, 30). Fire #8, located close to the Ninety Mile Tank, continued to burn actively for several weeks before undertaking a major run on 9 January under the influence of extreme high temperatures and strong north-westerly winds. On this one day the fire front spread about 65 km, extending to the margin of the agricultural lands around Salmon Gums. The final area burnt by Fire #8 was about 145 000 ha, much of it burnt at very high fire intensites which resulted in severe damage to stands of eucalypt woodland.

As was the case in the Malcolm area, there were also substantial areas which showed no evidence of fire activity sice before 1950.

There were several instances where two fires had occurred within 40 years, notably:
- to the west of the Ninety Mile Tank which was estimated to have burnt during the decade of the 1950's and then again in 1972/73;
- the area extending on a north-west to south-east axis around Peak Charles which also burnt in the decade of the 1950's and again in 1991.

More limited areas which had experienced three fires since 1950 were also identified.

Discussion

The results of this study demonstrate that extensive fires have been a feature of the landscape in the Malcolm and Lake Johnson areas for at least the past four decades, and almost certainly much longer. Preliminary examination of photographs and satellite imagery from other areas confirms that similar fire regimes have occurred throughout the south coast and semi-arid hinterlands. Individual fires exceeding 100 000 ha are not uncommon. The remote location and relatively frequent occurrence of dry summer thunderstorms throughout the region strongly suggest that lightning has been responsible for many of these fires. There is some evidence of an episodic pattern of fires with major fire years in the mid to late 1950's, the early 1970's and 1990/91.

A single high intensity fire can cause severe physical damage to trees which make up the eucalypt woodlands so characteristic of the semi-arid zone. Large mature trees can be completely killed by defoliation, severe crown scorch and severe heating of the stem. Seedling regeneration does however appear to be prolific in the most severely damaged areas of the 1990/91 fires, and in less severely damaged areas mature trees are recovering despite damage to crowns and stems.

Present-day woodland communities show ample evidence of the effects of past fires in a variety of forms. These include:

- cohorts of even-aged regeneration beneath fire-killed veteran trees,
- the presence of multiple fire scars on stems of old trees,
- stands that are under-stocked, apparently because of the effects of past fires.

It is sometimes argued that the sparse fuels typical of woodlands discourage or even prevent the spread of fires within them and that almost any fire poses a threat to the continued survival of eucalypt woodlands. On the first point, given the right weather conditions woodlands clearly will burn on an extensive scale. Regarding the second point, I believe that there is clear evidence that woodlands have developed and can persist in the presence of periodic disturbance by fire. Much of the variation in stand density, species composition and age structure of woodlands may in fact be the product of chance fire events, and in particular the length of the period between fires.

Following the 1990/91 fires dense swards of native grasses, including *Stipa hemipogon* developed in areas of burnt mallee and woodland. Such swards are rarely seen in long unburnt vegetation in this area. Presumably this species and others like it have a substantial bank of soil-stored seed which can remain viable for long periods (greater than 50 years). These grass swards persisted for 2-3 years after fire and were abundant in June 1993 but largely disappeared by May 1995. During the first few years after fire the grass was sufficiently dense to carry fire under dry, windy conditions. If further fires had occurred at this time, much if not all of the seedling regeneration of tree and shrub species established following the 1990/91 fires would almost certainly have been killed, resulting in dramatic and long-lasting changes to the vegetation. Whether or not this does occur periodically in the natural course of events is uncertain, but would be worth investigating.

Ring counts on stem sections from *Callitris* proved to be a useful means of coss-checking fire ages determined from remote sensed imagery. On most section the growth rings were quite clear, although some false or incomplete rings were observed. Some error would be introduced into age estimates on individual trees because of variation in the time taken for seedlings to attain the sectioning height of 0.2 m. Seedlings are slow growing and it is likely that 3-5 growing seasons would be needed to reach this height. Regeneration of *Callitris* older than 20 years was quite often still less than 1 m in height.

The slow growth of *Callitris* makes it vulnerable to local extinction by fires at relatively short intervals. Small quantities of seed were found on plants that were about 18 years old. The present-day distribution of *Callitris* is likely to have been strongly influenced by the sequence of past fires. Evidence to support this proposition was found in the form of distinct boundaries on some stands that coincided with past fire boundaries but did not appear to be related to differences in soil characteristics. Similarly, dead *Callitris* were found in relatively old vegetation (>20 years since fire) some distance from the nearest live trees, with no younger regeneration present. In both cases the areas from which *Callitris* was absent had been burnt twice within 20-30 years, while the fire interval in the areas where it persisted had been considerably longer.

Callitris may grow to considerable age, and a number of examples of trees older than 100 years since fire were recorded. The oldest tree recorded in this study was 135 years, and was taken from a stand of similar sized trees near the Peak Charles turn-off that had been killed by a fire in the early 1970's. Several other stands of old trees were found along the Lake King Norseman road, and no doubt also exist elsewhere in both study areas although they may be difficult to locate. As this species is fire sensitive even when mature, the clear implication is that some areas of the landscape remained fire-free, at least on the scale of hectares, for more than a century.

We observed little seedling regeneration of *Callitris* following the 1990/91 fires, despite the apparent abundance of seed capsules on most mature trees. The reason for this is uncertain, but may include factors such as delayed germination and emergence, and poor survival due to adverse seasonal conditions or grazing. Many stands appeared to be uneven-aged and not dependent on fire or disturbance for regeneration. Regeneration ecology of the various *Callitris* species would be a worthwhile area for further study.

Conclusion

The landscape of the Lake Johnson and Malcolm areas has been subject to extensive fire activity over at least the last four decades, and almost certainly for much longer. There is ample evidence that the woodland and shrubland communities we see today have evolved with and are the product of periodic fires. Lightning is an important cause of fire, and many of these fires grow to a large size. There is some evidence for an episodic pattern of fires with peaks of greater activity every two decades or so. There are many clues as to the historic role of fire in this environment if we can learn to interpret them correctly.

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